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Water Year Book
1981-1982

Water and the economy

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Preface

This edition of the Canada Water Year Book is the fifth in the series reporting on freshwater resources in Canada. The first edition, for 1975, provided broad general coverage of Canada's water resources. The second, for 1976, looked in detail at water management in Canada. The third, for 1977-1978, dealt with water data and described the field, office and laboratory programs producing water data. The fourth edition, for 1979-1980, provided an overview on water research across Canada. Unlike the last few editions that have carried a special theme, this latest edition, for 1981-1982, deals with a large number of subjects, each with its own special message.

If one had to select the most important message in the 1981-1982 edition, there is no doubt that it would be the one contained in the opening chapter which reveals that water is an extremely valuable resource of growing importance to Canada's economy. Because water generally has seemed plentiful throughout Canada, Canadians have failed to appreciate the vital role that water serves in their daily economic and social lives. The chapter addresses problems confronting water managers and water's vulnerability to man's excesses if the problems are allowed to go unchecked. It then goes on to present possible initiatives in water planning and management which not only solve many of the problems but also represent opportunities for economic development.

In later chapters, the reader is made more aware of the extent of water use in Canada as well as the impacts from too much water (floods) or too little water (droughts). Also discussed are measured being undertaken to improve planning and management of water resources across Canada and along the Canada-U.S. boundary.

The closing chapter deals with water-related matters of current interest, with emphasis on involvement by Canadians in freshwater programs overseas.

Calendar of Events

Severe Storms 1981-1982

Winter blizzards, violent hailstorms and thunderstorms, and heavy rainfalls and flooding inflicted death and considerable property damage in many parts of Canada in 1981 and early 1982. Some of the more notable events are described briefly below.

Winter 1980-81

A series of five snowstorms during the first 23 days of January crippled parts of the Maritime Provinces. Particularly hard hit was the Annapolis Valley of Nova Scotia, where Greenwood had l35 cm of snowfall in January, almost twice the normal. On March 17, an intense snowstorm struck parts of central and southern New Brunswick; Fredericton received 46.4 cm of snow in 24 hours and Charlo, 24 cm in 6 hours.

Summer 1981

A number of violent storms occurred throughout Alberta in July. On the 13th, the Lethbridge area was battered by a violent hailstorm. The next day in Edmonton, a devastating thunderstorm deposited 58.8 mm of rain and hail in less than 3 hours. On the 28th, Calgary and surrounding farmlands were pounded with 5 cm hail; damage was estimated at more than $15 million. In other provinces, severe summer storms caused local flooding and extensive property damage. In Ontario, a storm on May 11 caused flooding in the Toronto area; a major storm in the third week of June caused high runoff and severe erosion problems in some of the smaller streams in southern Ontario. On July 19th, a severe storm struck north Toronto and the neighbouring towns of Maple and Thornhill. On August 4, a recorded deluge of 115mm of rain, an all-time 24-hour rainfall record, occurred in Ottawa. In Quebec, heavy August rains caused the river Bras Saint-Nicolas to overflow its banks near Quebec City. Some 250 homes were affected and more than 400 families were evacuated.

Fall 1981

Heavy rains caused serious local flooding in several communities during the fall. On October 1, at Windsor, Ontario an 89 mm downpour in 24 hours broke all previous records for short-duration rainfalls. Between October 7 and 9, heavy rains fell in the Gaspé Peninsula during which 245 mm fell at Mont-Louis. At the end of October, parts of British Columbia's south coast were deluged by heavy rains. Weekly rain totals exceeded 230 mm in some places.

Winter 1981-82

Eastern Canada experienced a number of crippling storms in January and February. In Ontario, extremely cold temperatures, locally heavy snowfalls and high winds caused heavy snow, drifting and high wind chill values. Little melting occurred until mid-March. In central Quebec and Labrador and the Gulf of St. Lawrence, the area was hit with a particularly intense storm on January 18 with blizzard conditions that threatened public safety. The Gulf was hit a month later by a paralyzing storm, the effects of which lasted a week. The Atlantic Provinces were struck by a succession of major snowstorms in January, on the 2nd, 14th and 15th that brought the region to a standstill. In February, intense storms occurred on the 3rd during a wide-spread freezing rainstorm, on the 14th-15th when the oil rig "Ocean Ranger" sank with a loss of 83 lives and again on the 21st-22nd with a wind and snowstorm, the aftermath of which isolated Prince Edward Island for a week in 7 m deep snowdrifts.

Spring and Summer 1982

A freak storm on the 29th and 30th of May battered southern Alberta and Saskatchewan. Snowfalls of 20 to 60 cm were whipped by strong winds into drifts more than two metres deep. Transmission lines and trees were felled and thousands were without power. At least two traffic fatalities were reported and thousands of newborn spring calves died.

The summer of 1982 was noted for its unfavourable weather. In Toronto, the highest temperature was 30°C, the lowest such maximum value this century; a minimum temperature of 5°C was the lowest recorded since 1915. The prairies experienced severe weather, with heavy rains, hail, funnel clouds and tornadoes in July and August. Heavy frost occurred in the northern agricultural areas of the prairie provinces on August 27. Damage to the cereal crop was extensive. In Ontario, heavy frost on August 29 in southern Ontario and Quebec was the earliest widespread frost in several decades and crop losses ran to $200 million in tobacco areas.

Federal-Provincial Cooperation

The governments of Canada, Yukon Territory and British Columbia announced the signing of a $2.2 million Yukon River Basin Study Agreement in November 1980. The purpose of the agreement is to study current and foreseeable uses of the water and related resources, highlight specific areas where resolution of conflicts is needed, and provide a framework for future resource management decisions.

The governments of Canada, Quebec and Ontario released the final report of the Ottawa River Planning Committee in March 1981. The Committee's purpose was to examine methods for reducing flooding without seriously affecting other water uses, in particular hydroelectric production. It concluded that it is impractical to eliminate all flood damage; however, by integrating operation of the many storage reservoirs on the river, and a combination of other strategies, flood damage can be significantly reduced. The Committee recommended that a permanent Federal-Provincial Regulation Planning Board be set up to oversee the ongoing operations of the principal reservoirs in the basin.

The report on the Canada-British Columbia Thompson River Preplanning Study was released in April 1981. The report identified the conflicting demands placed on the basin's water resources by users such as agriculture, forestry, urban and industrial development, and fisheries and recreation and recommended that a three year planning study be undertaken.

The Canada-Nova Scotia Shubenacadie-Stewiacke River Basin Study has been completed and the final report released. The study, to evaluate the resources of the basin from the outskirts of Dartmouth to the Minas Basin, was prompted by a rapidly expanding population concentration, with resulting development pressures. The report does not reveal any current outstanding problems but warns that water problems could emerge in the near future unless a planned approach to development is followed.

Considerable negotiations between the Government of Canada and several provincial governments took place in 1981 under the national Flood Damage Reduction

Program. Details on these agreements are presented elsewhere in this edition. A few highlights are as follows:

- A new Manitoba Flood Forecasting Agreement and an agreement to amend existing General, Mapping and Studies Agreements were signed in March 1981.
- The Province of Newfoundland and Labrador became the seventh province to join the program with the signing of General and Mapping Agreements in May 1981.
- A new Montreal Flood Control Agreement was signed in June 1981 authorizing additional funding and an extension in time to complete dyking around surrounding communities, and to complete ongoing studies.
- A Canada-New Brunswick agreement to amend the existing General, Mapping, Studies and Flood Forecasting Agreements was signed in July 1981.

By August 1982, a total of 22 areas (covering approximately 180 communities) had been designated under the national Flood Damage Reduction Program, nine more than the total reported in the 1979-1980 Year Book. The intent behind designation is to reduce flood damages by identifying flood risk areas and discouraging further development in flood vulnerable areas. The latest designations in the order of their occurrence are 1) Souris and 2) Elie, both in Manitoba; 3) Oromocto to Lower Jemseg, New Brunswick; 4) Moose Jaw, Saskatchewan, 5) the lower Richelieu River in Quebec, 6) Lower Fredericton to Lincoln, New Brunswick, 7) Brandon, Manitoba, 8) L'Assumption River basin in Québec, and 9) White River, Ontario.

International Cooperation

The IJC released its final report on Water Quality in the Poplar River basin in February 1981. It concluded that the Poplar River Generating Station of the Saskatchewan Power Commission will not cause any substantial adverse water quality impacts in the United States, and that there are no compelling reasons for delaying the operation of the existing two generating units.

The IJC also released its final report dealing with flooding on Lake Champlain and the upper Richelieu River in February 1981. It concluded that although some measure of flood control is technically feasible, it could not reach a decision as to the desirability of flood control works because of environmental concerns in the United States. Official level meetings, first between the federal government and Quebec, and then with the United States, will be required to resolve this longstanding issue.

The International Lake Erie Regulation Study Board submitted its final report to the IJC in September 1981. The Board concluded that construction of regulatory works at the outlet of Lake Erie to reduce the extreme high water level would not be economically feasible. It recommended that the IJC encourage coastal zone management practices as a means of reducing flood and erosion damages along the Great Lakes shoreline.

The International Great Lakes Diversions and Consumptive Uses Study Board presented its final report to the IJC in August 1981. Based on the conclusions in the report, the Board has recommended: 1) that no further consideration be given to the concept of managing Great Lakes levels and outflows through the manipulation of the existing diversions, and 2) that the IJC recommend to governments that a mechanism be established for institutional consultation so that monitoring can be undertaken and appropriate public policies can be formulated to address potential impacts of new or increased diversions and consumptive uses.

Canadian and U.S. Officials met several times in the past two years to continue consultations on technical outlines related to the Garrison Diversion. For the first time, a proposal was outlined by U.S. officials which would eliminate essentially all of the return flow to Canadian waters. Feasibility studies are under way in the United States on this new proposal, and technical details will be examined closely in Canada.

In October 1981, the Government of Canada approved a contribution of $65 million for sewage treatment facilities in the Great Lakes basin in Ontario to meet Canada's obligations under the Canada-U.S. Water Quality Agreement. This payment raises to more than $600 million the federal contribution to complete the massive $1.7 billion municipal cleanup in the Canadian Great Lakes basin. In July 1982, 10 years after the first such agreement was ratified, the Ministers of the Environment for Canada and Ontario signed the 1982 Canada-Ontario Great Lakes Agreement, a cooperative agreement to meet Canadian commitments under the Canada-U.S. Great Lakes Water Quality Agreement.

The contribution of water resources to the economic and social well being of Canadians has kept pace with, if not exceeded, the corresponding growth in Canada's population and economic production. The period since 1945 has seen massive development of water resources, including the St. Lawrence Seaway Project, the Nelson River Power Development, the South Saskatchewan Project, and the Columbia River Treaty Projects, to name only a few. While electric power is an important purpose served in these and numerous other projects, some projects have also served to enhance navigation, irrigation and flood control as well as water supply and sewage treatment for large and small communities.

Some Aspects of Water Use

Water serves a myriad of purposes. Domestic use of water by households; industrial use of water as a process input, as a cooling agent and as a medium for waste disposal; and irrigation use of water in agriculture, are all withdrawal uses, inasmuch as they remove water from its natural course. Other uses – fishing, transportation, recreation and hunting – depend on water as it occurs naturally, and thus are non-withdrawal uses. Hydroelectric generating stations, which make use of the energy inherent in flowing water, also are non-withdrawal users. Clearly, water affects almost every aspect of Canadian society and, inevitably, as demand exerted on water resources intensifies and diversifies, conflicts will occur. Careful and imaginative planning will be needed to alleviate many of these conflicts.

Withdrawal and non-withdrawal uses can be further classified in terms of consumptive and non-consumptive uses. Non-withdrawal uses will not usually consume water, but withdrawal uses exhibit various levels of consumption, ranging from a minor amount in manufacturing and municipal uses to relatively large amounts in agriculture and mining. Statistics on water use, and a discussion of both withdrawal and non-withdrawal uses, as well as water consumption, appear later in this Year Book, and a review of that information before proceeding should help to set the scene for the discussion which follows.

Since 1945, development of water resources has included massive installations like this project on the Peace River in British Columbia

The relationships between water and economic development are complex and imperfectly understood. In general, raw materials, markets and transportation costs will tend to be more important than water in attracting an industry to a region. But once the decision to locate in a given region has been made, water often becomes an important factor in determining the precise siting of the plant. Conversely, the influence of economic growth on water can be very great indeed. Through development of industries and municipalities, water quality problems arise or worsen. Also, development generates the need to expand water supply systems. An example of economic growth having great implications for water resources can be found in western Canada where a Department of Regional Economic Expansion study projected increased employment of up to 1.3 million persons by 1990. Sixty percent of this new employment is expected to be located in the dry prairie region. This trend points to increasing pressures on already short water supplies, large expenditures to augment existing supplies, and deteriorating water quality.

Water as an Economic Good

Traditionally, water has been considered a free good, and charges for its use have been related to the costs of treatment prior to use, distribution and pollution abatement. In contrast to most other natural resources, no commodity charge is attached to water itself. Economic principles show that when a good is undervalued it tends to be overused. Hardin applied these principles to show why common pastures in mediaeval England deteriorated through overuse, and the same principles apply to water resources. A case in point is the deterioration of water quality. Because water use for the assimilation of pollutants is underpriced, if it is priced at all, the rational private user will discharge all his wastes to receiving waters. Many polluters doing precisely this contribute to gross pollution of inland and coastal waters. The same type of argument can be made in connection with municipal water supplies, where underpricing leads to wasteful use which, in turn leads to uneconomic expansion within the water supply systems. Research has demonstrated countless times that municipal water demand is indeed a demand in the true economic sense, and that a more rational pricing structure would lead to water conservation and to substantial social benefits.

The Economic Value of Water

Because water has been considered a free good in Canada, few attempts have been made to establish its value in economic terms. There are unquestionable needs for such a value, however, among them the need to justify program expenditures, and the need, when water is in short supply, to allocate it to the highest valued users.

Two approaches can be used to estimate a value for water. The first is to present the values of production in industries where water is a large and vital input. The second approach is based on the cost of the next-best alternative to current water use. For example, the value of water for cooling purposes would be the cost of installing and operating a recirculation system.

i. The Value of Production Approach: Water's importance to the production of goods and services in Canada is evident in several areas.

Water is a vital input for agriculture, fishing, mining, manufacturing and power generation. In 1975, the latest year for which complete data are available, the value added by these industries totalled $58 billion, representing about 35% of the Gross National Product. In 1980, this total grew to about $67 billion (in 1975 dollars).

Water is also important in another area – recreation. Recent statistics suggest that of the $210 billion family income in Canada in 1980, about 7% was spent on recreation, and about 75% of recreational activity was water oriented. On this basis, $11 billion must have been spent on water-oriented recreation in Canada during 1980.

Annual expenditures made for water management by both governments and private industry are enormous. In 1978 alone, $4 billion was spent to meet the combined administrative, operation and maintenance, and construction costs for water systems in Canada.

These sums are truly immense, and show the importance of activities attributed to or supported by water. However, they reflect the costs of all factors of production and thereby overstate the value of water. The "next best alternative" approach is a better reflection of the true economic value for water.

ii. The "Next Best Alternative": The concept of "next best alternative" places a value on actual water use. Only an indication of these values will be given here because this subject needs much more research.

In hydroelectric production, water is the primary input. Without this means of power production, Canada would have to rely solely on thermal generation. Assuming that Canada's hydroelectric generation in 1980 had to be produced in oil-fired plants, the costs involved for fuel alone would have ranged between $9 billion and $12 billion, depending upon whether domestic prices or world prices of oil are considered.

A recent study within Environment Canada estimated that withdrawal water uses throughout Canada had a combined value of about $1 billion in 1980. Although the alternatives to most of the non-withdrawal uses have not yet been evaluated, it is clear that their values also would be large.

Even with this limited amount of work, the annual value of water in all its uses is estimated to be in the $10 billion to $20 billion range. However, much more work will be required before this figure can be defined more precisely.

The most important points that can be concluded from this exercise are that water is an extremely valuable resource and the management of this resource is extremely important for Canada's economy, even though many of the benefits of good management are indirect.

Investment in Canada's Water Resources

Major expenditures are directed each year to the development of water resources facilities across Canada. Although the intent here is not to deal in depth with this subject, enough information has been compiled to show that water and water-related expenditures constitute an increasingly important share of aggregate economic activity in the national economy. On an average annual basis (after correcting for inflation), water-related construction expenditures during the 1970s have increased 5.1% per year in comparison to the 3.8% per annum growth in gross national product.

Table 1 has been produced to indicate the actual expenditures and the corresponding value in 1971 dollars of major water-related projects in selected years from 1971-1980 inclusive. The table shows that actual total expenditures for the various categories have more than tripled, from almost $2 billion in 1971 to $6.5 billion in 1980. After adjusting for inflation, however, the true growth range is from $2 billion in 1971 to some $3.1 billion in the late 1970s, for an overall increase during the decade of some 55%.

Of the total water-related construction expenditures, roughly 60% has been devoted to the construction of electric power generating facilities, transmission lines, and distribution facilities. Water works and sewer systems were next with some 30% of all expenditures. Marine structures, dams, and facilities for irrigation and similar requirements accounted for the remaining 10%.

Another area of major spending in the water resources field relates to operation and maintenance (O&M), the ongoing costs to keep existing facilities operating. Although this has not been looked at as broadly as construction expenditures, some review of municipal government expenditures for water purification and sewage collection has been undertaken. For example, in 1976, the actual cost of O&M for water purification and sewage collection by municipalities totalled almost $1400 million. After correcting for inflation (using the implicit price deflator for gross national product) the O&M cost (in 1971 dollars) comes to some $880 million in addition to the $2 800 million of construction expenditures (also in 1971 dollars) in 1976. It is evident, therefore, that both investment for construction, and expenditures for O&M in water purification and sewage collection, are large.

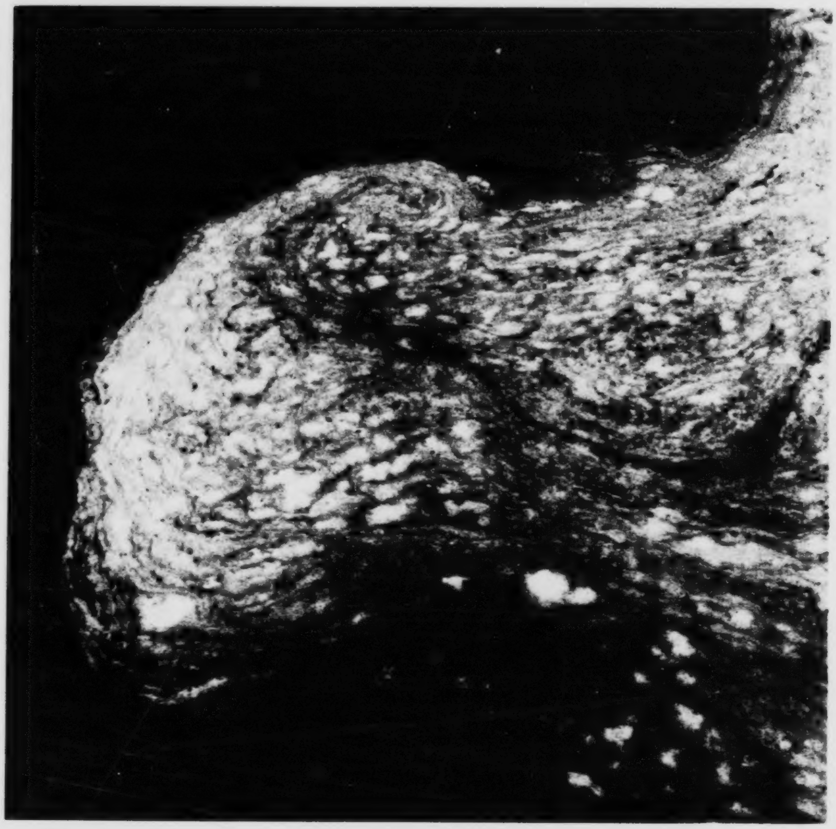
Economic Opportunities Arising From Water Management

Because water has generally seemed plentiful throughout Canada, Canadians have failed to appreciate the vital role that water serves in their daily economic and social lives. Seldom is a question raised as to whether there will be enough water to meet the needs of Canadians over the foreseeable future, or whether its quality will be maintained, notwithstanding the many uses to which man subjects it. These questions are addressed in the sections which follow in terms of the problems confronting water managers and water's vulnerability to man's excesses if allowed to go unchecked. Also dealt with are possible initiatives in water planning and management which not only solve many of the problems but also represent opportunities for economic development.

	1971	1974		1977		1980	
	Actual	Actual	In 1971 dollars*	Actual	In 1971 dollars*	Actual	In 1971 dollars*
Marine Structures, canals, dredging, etc.	120	220	160	240	140	260	110
Waterworks and Sewage Systems	590	1 060	810	1 670	930	2 000	880
Dams, Irrigation and Reclamation	60	110	80	160	90	200	90
Electric Power Stations and Distribution	1 190	1 820	1 370	3 360	1 880	4 070	1 790
Total	1 960	3 230	2 420	5 430	3 040	6 530	2 870

* derived using the implicit price deflator for gross fixed capital formation

Two principle dimensions become apparent in an overview on water management problems in Canada. Water quantity problems form one of these dimensions; water quality problems form the other. This does not imply the absence of significant relationships between the two dimensions. On the contrary, water quality problems often are made worse by inadequate supplies just as poor water quality can contribute to inadequate supplies. For simplicity, these two dimensions are separated and dealt with individually in the following.



Initiatives in water planning and management are possible that not only offset water quantity or water quality problems such as these but also represent opportunities for economic development.

Water Quantity

Although Canada has an abundant supply of water in the aggregate, time and space distributions of the resource have created water shortages in some instances and floods in others. This section focuses on these problems and, where relevant, attempts to quantify their significance.

i. Supply/Demand Imbalances

Table 2 contains estimates of aggregate water use and consumption in the principal river basins of Canada for 1980, 1985 and the year 2000. Also shown are records of reliable river flow in the basins to indicate the minimum supply available for withdrawal on a monthly and annual basis. When water use data are displayed in this manner, they show a spatial pattern of daily use which can be compared to water supplies in that basin. This is not to imply that the withdrawals shown are obtained directly from the reliable supply. In the North Saskatchewan River, for example, little of the water withdrawn comes directly from the flow in the river. Nevertheless, there is no doubt that the consumption associated with these withdrawals already has influenced the flow in the river and as time goes on this effect will become more pronounced.

		Supply		Water Use					
		Reliable Flow[1]		Total Daily Withdrawal			Total Daily Consumption		
		Annual	Monthly	1980	1985	2000	1980	1985	2000
1	Fraser	258 212.80	61 152.79	2 413.9	2 723.9	3 998.84	571.15	630.95	848.01
2	Okanagan	4 636.92	1 100.13	850.11	945.58	1 309.24	354.66	404.66	554.75
3	Columbia	137 289.20	51 824.40	1 645.65	1 941.15	3 195.85	150.43	168.75	260.18
4	Yukon	171 836.80	40 454.85	54.55	68.19	104.55	22.73	22.73	40.92
5	Pacific Coastal	841 010.00	100 293.85	4 650.59	5 737.04	9 569.33	284.51	335.17	524.66
6	Mackenzie	468 238.00	56 261.30	81.83	95.47	163.65	31.83	36.37	63.65
7	Peace-Athabasca	218 208.00	67 975.14	1 536.55	1 863.66	3 309.48	784.36	948.64	1 674.31
8	Arctic Coastal	171 658.80	61 869.24	—	—	—	—	—	—
9	Milk	381.86	0.00	731.90	881.93	1 582.01	104.00	114.08	159.67
10	Churchill	88 192.40	73 631.56	172.75	195.48	318.21	22.73	27.28	36.37
11	Nelson	39 413.62	18 834.06	836.47	981.93	1 600.19	104.57	122.74	181.84
12	North Saskatchewan	15 092.72	1 809.31	10 578.53	13 060.86	24 721.15	850.42	994.56	1 729.04
13	South Saskatchewan	12 501.50	2 982.18	7 119.04	8 028.24	11 660.46	3 287.18	3 674.84	5 280.80
14	Red-Assiniboine	2 863.98	340.95	3 868.66	4 686.92	8 469.21	343.77	390.87	568.92
15	Winnipeg	41 732.28	34 881.47	677.36	809.19	1 377.44	37.12	41.84	69.96
16	Northern Ontario	367 319.20	92 986.61	640.99	759.18	1 208.34	36.52	41.10	73.07
17	Northern Quebec	927 384.00	222 149.38	109.11	131.84	240.93	13.54	13.64	27.28
18	Keewatin	246 020.40	58 707.04	—	—	—	—	—	—
19	Lower St. Lawrence	135 925.40	65 066.90	12 456.04	15 065.44	23 711.93	849.20	945.50	1 207.32
20	Upper Great Lakes	145 472.00	104 483.44	13 751.65	19 793.28	44 841.75	526.81	606.74	1 131.43
21	Southern Ontario	32 094.76	11 496.83	37 718.16	49 196.81	98 639.11	1 366.03	1 615.91	2 544.73
22	Ottawa	134 561.60	80 477.84	2 796.79	3 277.66	5 291.54	250.37	277.85	414.47
23	Quebec Coastal	609 164.00	220 158.23	2 132.07	2 550.31	4 073.22	154.79	166.70	259.71
24	Newfoundland-Laborador	595 526.00	212 820.99	2 577.50	3 059.47	5 186.86	152.78	180.74	294.05
25	Maritime Coastal	166 362.40	56 020.36	10 869.49	13 306.15	24 630.24	271.09	309.07	472.20
26	Saint John	49 551.40	22 748.18	1 595.64	1 900.24	3 232.20	67.80	77.92	114.58
	TOTAL	5 699 861.24	1 710 887.05	120 084.43	151 869.09	283 463.87	10 636.49	13 327.85	19 981.82

Source: Inland Waters Directorate

1. All flow data (reliable supplies) reflect the effects of natural and artificial storage, which have a greater influence on monthly supplies than on annual supplies.
Reliable annual flow is that flow which would be available 90% of the time, or 9 out of 10 years.
Reliable minimum monthly flow is the lowest monthly flow experienced in 10 years.

The Mackenzie and Great Lakes basins have been subdivided for this compilation, thus southern Ontario (#21) does not reflect the flow contributed by the Upper Great Lakes (#20), nor is the U.S. share of any international river shown here.

Issues Associated with Supply/Demand Imbalances: The supply and total use data shown in Table 2 reveal that on a monthly basis, there are six basins where current and future demands either exceed, or are near the reliable minimum monthly flow, namely:

- Okanagan
- Milk
- North Saskatchewan
- South Saskatchewan
- Red-Assiniboine
- Southern Ontario

These six basins are the ones where water shortages are most likely to occur in the future. Even annual flow is inadequate to meet projected uses in most of these basins.

While most of the six basins are in the drier areas of the country, southern Ontario represents an area not normally associated with water shortages because of the presence of the Great Lakes. In southern Ontario, water shortages as such are not anticipated, but considerable capital will be required to construct water distribution networks in areas where demands outstrip available supplies. The supply/demand imbalances identified will continue into the future, and probably be exacerbated as demands grow, and consequently, more water use conflicts will occur. For the water-short basins, water needs for the thermal power generation sector are growing fastest, at 8.2% annually, followed by mining (4%), manufacturing (3.7%), agriculture (3.0%) and municipal and rural residential (2.7%). It should be noted that the prime industries in many of these six basins (e.g. agriculture in the western basins) are highly water-dependent. Also, the economic growth potential in these basins is above average over the longer term.

The amount of water consumed during use is an appropriate measure to compare with supply, for it represents the amount lost to the local environment as a result of economic activities. The total daily consumption of water in Canada rose to about 10 640 mLd in 1980, and could rise to 18 530 mld by the year 2000. By this measure, only the Milk, the North Saskatchewan, the South Saskatchewan and the Red-Assiniboine basins experience total daily consumption in excess of short-term supply. Water consumption, however, tends to be heaviest in the summer months when supplies may be low, thereby having an effect somewhat greater than suggested by the totals in Table 2. Also, the table understates consumptive use by failing to allow for minimum flows required for pollution abatement and navigation. These amounts are unavailable for withdrawal uses.

Possible Initiatives Associated with Supply/Demand Imbalances: Where required, supply/demand studies should be approached from two main directions: demand management and supply augmentation. Although these two directions are commonly recognized, traditional practice has tended to emphasize the latter. In carrying out supply and demand studies, economic principles are important, and both supply and demand should be considered as price-related functions. The economics-based approach will tend toward maximization of net benefits in solving supply/demand problems. Several initiatives are discussed below that could both alleviate attendant problems and enhance economic opportunities in the areas affected.

Water demand reduction, an often-neglected component of supply/demand management, can be met by various measures, three of the most common being: limiting the number of developments requiring large amounts of water; rationing, pricing and scheduling of water use amongst various user groups; and increasing the efficiency of use.

The first measure focusses on restricting new large-scale demands in water short areas by decreasing planned water withdrawals through recirculation; outright prohibition would be extremely difficult to enforce.

The second set of measures is based upon empirical findings that water demand will decline as its price rises. For municipal use, rationing and pricing fall largely to the municipal levels of government. An understanding of the economic aspects of water is beneficial to all levels of government, especially in planning infrastructure investments; the adoption of demand management may postpone or even cancel the need for new investment, releasing capital for other municipal improvements.

Improved water use efficiencies result when the same amount of water is used several times, through storage and recirculation, in-plant cooling or treatment, process changes and the use of new or modified raw materials. In agriculture, for example, reservoir storage can be improved by reducing seepage or evaporation; distribution is enhanced by lining canals; and farm application is made more efficient by using sprinklers instead of ditch-type irrigation methods. In other examples, projected thermal power plant demands in the Great Lakes basin could be reduced seven-fold by the year 2000 by using cooling ponds in place of once-through cooling systems, while increasing consumptive use by only 25%. Similar decreases could be expected in other areas of the country. Considerable potential also exists for converting municipal wastewater into potable water for reuse.

Both federal and provincial governments could serve a role in the pricing of water and improved water use efficiency by conducting research into the economic structure of water demands and by encouraging water reuse technology development. In addition to supporting and possibly funding these efforts, these governments could act as disseminators of research results regionally and nationally. Another area of economic payoff related to demand management is in the growth of a Canadian product market. Imports presently fill the domestic demand for water-saving devices but, with growth in demand, a domestic industry should be feasible. This would act as a stimulant to employment and would be consistent with actions to encourage manufacturing in Canada.

Water supply enhancement on a major scale will probably be required at some point in the future, as demand reductions will not always be possible. Increasing storage capacities is one action which can be taken in this connection. A second is large-scale interbasin water transfers. Both of these measures tend to be capital intensive, environmentally disruptive and time-consuming, and would be undertaken only after all cheaper options have been exhausted.

A cheaper and possibly equally effective supply measure is the increased use of ground water. Major aquifers in areas lacking surface water require much investigation and mapping. For example, in the Okanagan basin, there is evidence of the potential for combining surface water and ground water sources to alleviate water shortages during low flow periods. Potential exists also for ground water recharge through retention of spring runoff. This option is effectively an increase in an area's storage capacity. Issues requiring research are uncertainties about long-term aquifer yield, water quality, and hydraulic relationships between ground water and surface water.

Water supply enhancement has pronounced economic benefits as well as substantial costs. For example, low water levels in the Great Lakes in 1973 resulted in a 20% reduction in hydro generating capacity and the expenditure of $100 million on alternative energy sources. Water supply can also act as a catalyst for industrial development, and some day may play an important role in the development of Alberta's tar sands and heavy oil producing areas. Economic benefits can also accrue from construction of water supply and sewer systems. A recent study estimated that each one million dollars spent in this manner results in 35 to 40 person-years of employment and one-quarter million dollars in expanded local business.

All levels of government can play a role in minimizing water supply/demand imbalances by supporting research on both demand management and supply enhancement. Under a provision contained in the Canada Water Act, Environment Canada can assist provinces to undertake a wide range of research examining water supply issues, encourage the private sector to develop and market technologies to enhance water supply, and aid in the construction and operation of water supply projects.

The development of computerized data collection and satellite telemetry in the water quantity field may offer some unique opportunities for income generation. The vast size of the country makes distance a severe constraint on many activities, including data collection. But these disadvantages can be overcome if techniques of automated data collection can be developed to a high degree. This initiative also builds upon the high technology nature of the Canadian economy. Two economic advantages would flow from this initiative. First, it would lower the cost of data collection in remote and northern areas, where water data information in increased volume will be required in the future. Second, there may be a market for package systems in other countries, where water data collec-

In agriculture, farm application is made more efficient by using sprinklers instead of ditch-type irrigation methods.

tion is only beginning. This would generate foreign earnings, helping to alleviate current balance of payments difficulties.

Another area in which a major initiative would be timely relates to water supplies for the energy rich areas of Canada. This initiative would identify and analyze water supply conditions in energy production areas in the context of emerging demands. It would result in alternatives for augmenting supplies where required and an assessment of the benefits and costs of each alternative. The economic payoffs would be a contribution to Canadian energy self-sufficiency, with attendant savings in foreign exchange. Also, from the viewpoint of global political situations, it is very important that energy self-sufficiency be achieved as quickly as possible to overcome reliance on increasingly uncertain foreign sources. Canadian energy reserves will probably become increasingly important from a strategic point of view.

A final area of initiative would call for expansion in knowledge of the economic value of water. In the event of water shortages, or increasing conflicts between water users, allocation of existing supplies to high valued uses could partially forestall the need for structural measures to increase water supplies. Indications are that a water value study would be relatively inexpensive and would prove extremely valuable for future water management programs.

A recent study estimated that each one million dollars spent on water supply or sewer systems results in 35 to 40 person-years of employment and one quarter million dollars in expanded local business.

ii. Agriculture on the Prairies

As they enter the 1980s, the Prairie Provinces have the potential to sustain the rapid economic growth rate set during the late 1970s. However, the lack of secure water supplies is a major constraint to resource sector productivity throughout the prairies. The provision of an increased secure water supply from storage or diversions will release constraints not only on agricultural development but also on municipal and industrial development, with subsequent social and economic benefits. In addition, the soils of the prairies are deteriorating and concerted efforts directed toward the development and implementation of conservation practices are required in order to ensure long-term productivity of this valuable resource.

The deteriorating nature of farmland in Canada, of great concern to agriculturists, is described in the section headed droughts. The problems of limited water supply, which are fast becoming a serious constraint to water users on the prairies, are addressed below.

Issues Associated with Water Supplies for Agriculture: The primary source of streamflow of most of the major prairie streams is the snowmelt from the eastern slopes of the Rocky Mountains in Alberta. There is usually a small contribution of runoff from the western prairies, but it is erratic and unreliable.

Streamflow in prairie streams varies seasonally and annually, with high peaks in the spring and extremely low values during the rest of the year. In addition, the volume of runoff varies widely from year to year depending on the size of the winter snowfall and the occurrence of spring rains. Because of the variation in streamflow, water storage for streamflow regulation is required to provide a dependable supply.

The flow that occurs within a watershed can be manipulated by changing the operation of existing reservoirs, by effecting a more efficient distribution system or adding new reservoirs. However, if the demand for water continues to grow, the diversion of new water onto the prairies will be required if water is not to become a constraint to economic development. This condition will occur in southern Alberta in the foreseeable future.

The pace of prairie economic growth and its demands upon the soil and water resource are fast outpacing the capacity of the physical environment. Yet, natural resource development requires a relatively long lead time to either significantly augment or reallocate supply or to manage demand. The need for substantial trade-offs is emerging for both the water and soil resources as agriculture, industry, mining, power generation and other uses compete for these basic resources in an expanding economy. Upstream and downstream conflicts are emerging, particularly in drought years, where many uses depend on the same limited water supply. Resolution of such trade-offs will become a priority in the 1980s and 1990s.

Large projects also require long lead times for planning, design and construction. Because of the long time lag between commitment and construction and the realization of benefits, special economic evaluation issues are raised. Commonly, investments must be made a generation before benefits are realized. However, failure to make the investments will significantly reduce the ability of the next and continuing generations to achieve the objectives of economic diversification and stability. In view of the long-term nature of the benefits, projects must be sized in a flexible manner taking into account future uses. Projects sized on the basis of current demands become functionally obsolete in a short time and are very expensive to retrofit to meet increasing demands. Planners and decision makers must be cognizant of the multiple uses which may result from development and be prepared to make the necessary investments.

Use of water and soil resources raises significant environmental issues. In order to utilize water resources in the home or for irrigation, industrial processing or other intensive uses, the water must be stored and diverted from its natural course. Water that is not evaporated or otherwise used returns to natural water courses. The change in water regime and the degraded quality of the returning water affects the traditional stream uses. Because many prairie streams have already been dammed, these impacts have already occurred to some degree. The magnitude of these impacts can be moderated with appropriate consideration of environmental issues, and in some cases, in-stream uses can actually be enhanced.

Wide fluctuations in water flows between drought and wet years add to the costs of development. The more obvious and least costly methods of supplying water have already been developed, especially for irrigation and community supplies. The quality of prairie streams is decreasing as more use is made of their waters. Considerable attention is now being given to providing significant flows in streams to maintain acceptable levels of quality. Local supplies are now often fully committed, and demands are being met by more efficient use of available supplies and by constructing costly projects involving river diversions and larger storage reservoirs. The costs of such developments are several times higher than would be incurred if wide fluctuations in flow did not occur. These wide fluctuations increase the storage volumes required to ensure supply during droughts and increase the cost of spillway structures. Also, they can cause flooding problems during wet years with the result that separate flood control works such as diversions and dykes, as well as other measures associated with flood risk mapping and land use controls, often become necessary.

Initiatives Associated with Water Supplies for Agriculture: Initiatives to enhance agriculture through ensuring sufficient quantities of fresh water and development techniques for more efficient use of the water fall into short-term and long-term categories. Over the short term, improved water management and conservation techniques become increasingly necessary for purposes of both augmenting existing scarce supplies and maintaining water quality in the fragile prairie environment. Options available could include measures to reduce the water losses in the storage, transmission and delivery of water such as lining irrigation canals, correcting leaks in small storage facilities and community distribution systems; incentives for demand management such as water metering, seasonal pricing and inversion of water pricing for bulk users; upgrading the quality of industrial and municipal effluent to reduce adverse effects on already scarce in-stream supplies and to limit demand for dilution; developing water saving irrigation techniques; and encouraging water recycling.

To ensure proper management of land and water resources in the prairie region and to achieve projected production targets, accelerated research is needed to study

Over the short term, improved water management and conservation techniques become increasingly necessary for purposes of augmenting exising scarce supplies and maintaining water quality in the fragile prairie environment.

the critical problems of moisture supply, nutrient availability, salinity and erosion. The research should be inaugurated soon to provide information that would enable producers and policy-makers to optimize land use and develop improved management, tillage and cropping systems, while at the same time arresting or reversing the current soil degradation that threatens long-range production of western grain. Demonstration sites would be established on problem lands to illustrate effective management procedures and practical soil and water conservation measures.

Several major interbasin diversion proposals have been identified in the past. These proposals will be made again in the future as a means of relieving water constraints on the prairies. There are, however, a number of unknowns associated with these proposals that will take some time to research properly. Among these are questions concerning the long-term effects of biota transfer and the long-term water needs of the donor basins. This research work should get under way immediately.

Demand management options will also require close consideration for addressing prairie soil and water issues in the medium and long term. Substantial public and private investment in water demand management may be undertaken. Installation of water recycling equipment in energy and energy processing industries, cooling towers in thermal power plants, metering and pricing of urban water supplies, and incentives to hydro transmission through a western energy grid can pay large dividends in terms of the postponement of the capital costs of water supply augmentation.

Although there has been much skepticism about the economic viability of irrigation developments, recent professional literature indicates that former evaluations of the benefits of irrigation have been too narrow. Evaluations based solely on primary benefits ignore many factors which are unquantifiable in the short term. For example, many of the benefits of irrigation projects developed in the late 1940s and early 1950s are only now showing their true worth through the jobs provided, volume of economic activity generated and income stability provided through diversification.

Many earlier analyses assume factor prices remain constant, whereas relative real prices of agricultural inputs and commodities are changing rapidly. As commodity prices and land values increase, as has been the recent experience, irrigation development becomes more viable. In terms of the distribution of benefits, a 1966 study of the Eastern Irrigation District by the University of Alberta indicates that the following percentage distribution of benefits of irrigation may be appropriate: irrigation farmers, 11%; local areas, 22%; province, 32%; and Canada, 35%.

The drought of 1980 is a prime example of the value of irrigation when livestock operators in Saskatchewan had to rely to a large degree on Alberta-produced forage to maintain dairy and breeding herds. The benefit of irrigation during periods of drought is but one factor that has been neglected in determining the viability of Canadian irrigation projects.

In Alberta, an additional 200 000 ha could be irrigated by the year 2000 by constructing storages on the Milk, Bow and Oldman Rivers to utilize the province's share of flows in southern streams. This additional acreage would result primarily from extensions to the St. Mary, Bow River and Eastern Irrigation Districts. A potential of 2 million hectares exists but would require water importations from northern basins to serve further additions to existing districts and new areas in east-central and southeastern Alberta.

In Saskatchewan, some 80 000 ha could be developed in conjunction with Lake Diefenbaker, with possibilities of a further 100 000 ha served from this source when technological advances allow extensions to areas of soils requiring special care and treatment. There is a potential for an additional 400 000 ha in west-central and southeast portions of the province which would have to be accommodated by large-scale water transfers. Some of this potential could be realized in conjunction with adjacent developments in Alberta.

In Manitoba, there has been increased activity and interest in irrigation; however, the potential for development, although significant, is relatively small compared to that which exists in Alberta and Saskatchewan. Irrigation possibilities are being studied in the southeast and Assiniboine South Hespler areas. In the Shilo area, ground water sources are being explored and developed for irrigation. Also, several small projects in the 2 000 to 4 000 ha size, in which the province has expressed a keen interest, could be developed for market garden produce.

In addition to the foregoing developments, there are possibilities for group projects and individual irrigation schemes. This would promote diversification and stabilize the farm economy, particularly during periods of drought that all areas of the west experience from time to time.

The development of large-scale irrigation projects may have a degrading effect on the quality of major streams. This may result from accruals of salts leached from irrigated soils through surface runoff or subsurface drainage which are transmitted to receiving basins through return flows. Also, residues from agricultural chemicals and nutrients present water quality concerns for downstream users. Many of these problems can be avoided by proper application and scheduling of irrigation water. However, large expenditures are envisaged to develop the technology and controls necessary to ensure the maintenance of environmental quality for downstream users.

Because the prairie water resource is unevenly distributed and extremely variable, many rural communities and individuals must contend with insufficient water supplies of poor quality which impose constraints on diversification and development. Increased financial and technical assistance to provide secure, potable water supplies through the development of individual and community wells, reservoirs, pipelines, and diversion projects would remove many of the constraints to economic development and enhance rural living.

iii. Floods and Flood Control

Most Canadian cities have developed along the banks of rivers. Because waterfront land provides access to recreation, transportation, convenient water supplies and fertile cropland, it is often considered the most desirable land for development. As a result, urban development is continually encroaching upon flood plains.

Issues Associated with Floods in Canada: The possibility of flooding exists in all regions of Canada, although its severity varies widely. On the west coast, the major developed areas susceptible to flooding are located mainly along the lower reaches of the Fraser River and coastal streams, where the concentrations of population, industry and agriculture occur. Most rivers on the prairies are subject to periodic floods. Flooding can also occur in Canada's North during spring runoff, especially along larger northward-flowing rivers, whose downstream reaches are still frozen and cannot accommodate increased flows from southern headwaters. This type of flooding also occurs in eastern Ontario and Quebec's Eastern Townships. In the southwest portion of Ontario, flooding occurs as a result of local storms and the remnants of tropical storms which have their origin in the Gulf of Mexico. Montreal is sensitive to flooding under spring runoff, heavy rainfall conditions and the late retreat of river ice. Similar spring flooding is also experienced throughout the Atlantic Provinces.

Flood damage relief assistance amounting to some $30 million annually has been escalating and can only continue to increase as the standard of living rises and people continue to build in areas with a known history of flooding. In the past, governments built conventional flood control structures, but structures alone have their drawbacks. They are costly to build and maintain, they may not protect against all floods and they can engender a false sense of security.

A more sensible way of preventing future flood damages is to limit development in flood risk areas. This is the aim of the national Flood Damage Reduction Program which is committed to alleviating the human suffering and minimizing the costs of damages caused by floods. Under this program, the federal government undertakes jointly with the provinces the mapping of, or studies related to flood plain areas in Canada. Under agreements binding on all parties, governments agree not to support any future flood vulnerable developments in the designated flood risk areas nor to give flood disaster assistance to new developments locating there. Other parts of the program are concerned with developing flood forecasting and warning systems, and flood proofing methods. The national program is described more completely later in this Year Book.

Environment Canada plays a lead role in the Flood Damage Reduction Program. To date, seven provincial- and one territorial government, have undertaken to map flood risk areas under the national program, while negotiations with two other provinces are continuing.

Initiatives Associated with Floods in Canada: In the area of flood forecasting, Environment Canada, Ontario and Quebec are in the process of establishing integrated flood forecasting procedures for the Ottawa River basin, allowing the federal and provincial governments to alert basin residents to the time and intensity of a pending flood. Similar arrangements have been established in the Saint John basin in New Brunswick, and are being developed with Manitoba to forecast floods in the Souris, Red and Assiniboine Rivers. This service can provide sufficient lead time to evacuate persons and institute other emergency programs in the afflicted areas, thereby minimizing both human suffering and economic damages. Not only do such activities provide warning of impending peril, but they also have an influence on economic development within the area (the benefit cost ratio for the Manitoba forecasting lies somewhere between 2:1 and 3:1).

Flood prevention works too can offer an economic return. For example, it has been estimated that in 1979 alone, the Red and Assiniboine flood protection works in Manitoba have prevented $284 million in damages.

The economics of such examples speak for themselves, and accentuate the economic opportunity arising from water management under the Flood Damage Reduction Program. But the disruption to economic activity and damage to property caused by flooding will not be overcome without other measures being taken. Where it can be shown to be economically feasible, the comprehensive floodplain mapping program is expected to be continued until all flood-prone areas of Canada have been covered; similarly, flood forecasting is likely to be extended to other flood-prone areas.

The possibility of flooding exists in all regions of Canada (Maniwaki, Quebec, 1974).

iv. Droughts and Drought Proofing

Disruptions in water supply can have serious and pervasive effects on productivity, health, recreation and most activities. In Canada, the areas most often affected by drought conditions are the southern prairies and the interior portions of British Columbia. Other areas may occasionally be affected, but not to the same extent or severity as these. In the West, droughts have occurred periodically throughout Canadian history, with the most severe period being the "Dust Bowl" conditions of the 1930s.

Issues Associated with Droughts: All sectors of the economy are affected by drought conditions. But the impacts vary in severity depending upon the degree to which the sector relies on water and the importance of the sector in the regional or national economy. During the 1930s and earlier, impacts were most serious in agriculture, with very marked reductions in productivity, income and overall social welfare, worsening the already depressed nature of the economy. More recently, as exemplified by the dry period of 1976-78, evidence indicates that sectors other than agriculture will be the primary ones affected by future water shortages. Power generation suffered decreased production because of low water levels in reservoirs and reduced streamflow. Industries, such as pulp and paper, which are heavily water-dependent, suffer production cutbacks due to the lack of process and cooling water and because low water levels curtail log driving. Low water levels and flows also tend to worsen water quality, increasing municipal and industrial water treatment costs whereas deteriorating water quality damages the tourism and recreation trade through its adverse effects on the outdoor environment.

It is apparent therefore, without downplaying the effects on agriculture, that the effects of drought are much more pervasive, widespread and thus economically damaging, than they once were thought to be. A substantial problem in water management relates to the need to investigate and quantify these potential effects if one is to guide future drought proofing programs.

Drought proofing measures undertaken at any given location (for example, reservoir construction) may result in more serious shortages downstream, or produce similar adverse effects. For this reason, effective coordination between the various departments and agencies involved in drought-related activities is required.

Initiatives Associated with Droughts: Most of the initiatives suggested earlier under supply/demand imbalances are applicable to drought-related studies. Instead of repeating them, this section will attempt to establish an economic framework within which drought proofing initiatives should be evaluated.

First, the need for a sound benefit-cost framework is paramount in evaluating drought proofing proposals. There is a danger that decisions will be made on the basis of the philosophy that water is essential to economic development, and that the rigour of correct economic analysis will be overlooked.

Secondly, there is a need to consider alternatives in managing water resources for the maximum social benefit of Canadians. An essential question in evaluating proposed water augmentation for irrigation is "Can the products of irrigation be produced more cheaply elsewhere and brought into the region?" Project evaluation in a national context would not necessarily lead to curtailment of water supply augmentation, but would show in detail the costs of such developments vis-a-vis the most efficient alternative.

The third element in this framework for evaluating drought proofing proposals is the need to view proposals in a river basin context. If proposed projects ultimately damage downstream users, the costs involved may outweigh any local benefits resulting from project implementation. Because of its hydrologically integrated nature, the river basin is an ideal vehicle for evaluating the wider impacts of drought proofing measures.

A fourth element relates to the need to realize that water supply and demand are economic functions, and both functions should be defined economically when developing drought proofing proposals. If supply augmentation occurs without adequate study of demand characteristics, uneconomic investments will inevitably result.

A fifth element is the need to recognize the parallels between floods, discussed in the previous section, and droughts. They both relate to extremes in the water balance. Both are periodic in nature, although floods seem to be more frequent than droughts and occur more widely throughout the country. They both can be studied statistically in cases where relatively long periods of record are available. Floods are approached in Canada using, as a central tool, flood plain maps which define a probability-based flood risk zone. In the same manner, drought zones could be defined probabilistically, using rainfall, streamflow and evapotranspiration records. Both types of problems are open to a wide variety of solutions and, in the past, emphasis has been biased toward structural measures. For droughts, structural solutions, such as water supply pipelines, water diversions, irrigation, etc., are expensive, with private interests bearing only a fraction of total costs. However, these analogies tend to break down because the areas affected by drought are usually larger than those affected by floods, and droughts persist much longer and make the problem of defining drought probability more difficult. Nevertheless, the parallels might usefully be examined to determine whether elements and policies laid down in the Flood Damage Reduction Program may have application in a drought program.

v. Energy Generation

Energy issues dominate current events, not only in Canada, but internationally as well. Price rises, shortages (real or imaginary) and political action related to energy, spread through world economies and threaten realignments in global economic power. One vital factor often overlooked in the resulting confusion is the importance of water in energy production, a factor of particular importance in Canada. The country's good fortune in possessing large reserves of fossil energy resources must be tempered by considering that these reserves are located in water-short areas.

Issues Associated with Energy Generation: The water-energy interface has several dimensions. First, the exploitation of conventional oil deposits often requires deep-well injection of water to maintain pumping pressures. This requirement increases as fields near depletion. Thus, increased water use for this purpose can be expected over time; this use will occur in the more water deficient areas of the country. Second, the exploitation of unconventional

Canada's good fortune in possessing large reserves of fossil energy resources is tempered by the fact that these resources are located in water-short areas.

deposits, for example, tar sands, heavy oils, etc., requires very large amounts of water. By the year 2000, it is estimated that 375 million cubic metres of water will be required annually by tar sands plants, an eight-fold increase over 1980 requirements. While this region as a whole is not water-short, a very large capital investment for water distribution systems is implied by these water requirements. Water availability is currently a constraint to production; thus, one can expect that urgent action will be required to augment water supplies in these areas. Third, water use in energy extraction, especially in tar sands plants and for coal liquifaction, slurry pipelines and thermal cooling, generates heavy pollutant loadings, requiring special attention to pollution control systems. This need is increased by operation in a sub-arctic environment, where natural cleansing processes operate more slowly than in temperate areas, indicating that environmental damages can be more severe in northerly climates.

Several themes run through the interface between water and energy management. From an environmental viewpoint, compatibility between proposed projects and the environment is one of these themes. Future energy generation projects should be carried out with full knowledge of environmental consequences, and avoidance of the major detrimental ones. In the past, major projects such as the Bennett dam in northern British Columbia have caused environmental disruption. Current attitudes on the part of the public are such that these types of projects, for example, the Mackenzie Valley Pipeline, should not be permitted in the future without full consideration of social and environmental consequences. A second theme is the need to substitute renewable for non-renewable energy sources. This makes water-based developments ideal. A third theme is related to the large water requirements and resultant capital requirements for water supplies in new energy-producing areas, for example, the tar sands and heavy oil areas. Fourth, the impacts of thermal discharge must be addressed if environmental damage is to be avoided. Last, with energy developments on the scale anticipated, a market for Canadian technology (for example, the supply of low-head hydro equipment) is an important consideration. In this sector, made-in-Canada products could replace imports and help to improve future balance of payments.

Initiatives and Contraints Associated with Energy Generation: Hydroelectric power is both renewable and economical; it can also be developed in an environmentally compatible manner if adequate environmental assessment review and studies precede development. Also, hydro developments promise increased use of indigenous technology. Four types of sites could be highlighted: a. existing sites, including abandoned or decommissioned sites; b. sites with redevelopment potential; c. sites where head is developed for a purpose other than power production; and d. new or existing small scale, low head sites in remote areas not connected to a main power system, where electric energy is now provided from high cost fuels such as diesel oil.

There are a number of programs that represent current or recent initiatives to assess the potential for hydro development or to expand upon the knowledge and techniques of hydro development. These include the National Research Council's recent support to Barber Hydraulic Turbines Limited on "mini-hydro" development, and its current support of innovative design of a low-head small hydro development. The Department of Energy, Mines and Resources has supported a small hydro potential survey in British Columbia; it also has joined with Environment Canada in a national hydro inventory program; and it is supporting a demonstration project at Roddington in Newfoundland. The Departments of Energy, Mines and Resources, and Industry, Trade and Commerce are supporting a turbine demonstration project at Annapolis Royal, Nova Scotia, and both Ontario Hydro and Quebec Hydro are conducting assessment programs.

The lack of inventory information, including pre-engineering, environmental and multiple water use conflicts, and the lack of techniques for assessing and screening, including realistic economic evaluation techniques and criteria, stand as constraints to small hydro developments. These could be met in part by additional sponsorship at the government level for studies of hydro resource potential, and pre-feasibility studies at selected sites.

There is a lack of hydrologic data. Work to address this constraint would involve studies of the hydraulics and hydrology of small scale hydro and would include due attention to data collection for hydrologic and environmental assessment studies.

There is a lack of low cost techniques to assess environmental and dam safety aspects but this lack could be tackled through studies of these factors.

The costs of site design, custom construction of civil works and packaged generating equipment are high. The study of these costs for recent demonstration projects, and the support of a number of similar projects in categories not now covered (for example, abandoned sites, redevelopment sites, or at non-hydro dam sites) would probably result in improved techniques and improved costs.

In addition to the focus on hydro, the use of waste heat from thermal power stations and other industrial operations should receive greater attention along with the direct reuse of waste heat and indirect methods of thermal conversion. An example of direct reuse would be the location near thermal stations of industries or communities to utilize waste heat which now is discharged to surface waters.

The energy sector promises to be one of the most interesting and challenging for water managers in the 1980s and beyond. The vital role of water in energy production needs emphasis and more public visibility.

vi. Northern and Alpine Environments

Approximately half of Canada's land area is underlain by permanently frozen ground, or permafrost, and constitutes the area referred to as the North. The North contains much of the nation's natural resources and, as commercially exploitable resources in the southern areas become depleted, development will move northward. The future is likely to see very marked increases in activity in the North, posing problems for water resource management which, in many cases, will be radically different from those in the South.

Special Issues Associated with Northern and Alpine Environments: Most northern water problems can be traced to the climatic conditions of the area which generally become colder and drier with increases in latitude. The duration of freeze-up is longer, with much of the water supply held in a frozen state. Snow is often the

In the North, the duration of freeze-up is longer, with much of the water supply held in a frozen state.

dominant form of precipitation on an annual basis, with river flow being highly concentrated during the melting season. Frequent flash floods occur due to rapid snowmelt, low infiltration rates into the frozen soil, and low storage capacities in basins whenever these conditions combine. River and lake ice conditions become more rigorous as climates become colder with the result that frazil ice formation, ice jamming and consequent flooding increase in severity. As permafrost increases in extent and depth, more ground water becomes frozen, and hence immobile on a year-round basis.

The characteristics of this northern environment have several consequences for water users. Because of the seasonal nature of river discharge, especially in small basins where discharge can fall to zero in the mid- and late winter months, demand may outstrip supplies of water unless alternate sources, such as lakes or ground water can be tapped. Although the North is often portrayed as a lake-dominated landscape, this is true only of the Canadian Shield. In much of the remainder of the North, rivers and shallow lakes predominate; shallow watercourses freeze to their beds during the winter, again causing fresh water supply problems unless larger lakes are close at hand. Ground water is also much more difficult to procure, as the permafrost layer must be penetrated to reach adequate supplies. If aquifers are located, they may yield water of inferior quality. The length and severity of winter interferes with northern transportation, much of which depends upon the river system. River barging is restricted to the open water season.

On the other hand, frozen rivers and lakes can be used for winter transportation, as they are for example, in the Mackenzie Delta. Throughout the area, the potential for hydro development may be limited by river ice conditions and by the highly seasonal nature of streamflow.

Alpine environments are defined here as areas where glaciers have a significant impact on streamflow. These areas are significant in western and northern Canada. Two particular long-term phenomena are of interest because of their potential economic impacts: glacier recession and advance, and the response of glaciers during drought periods. For rivers where headwater glaciers exist, the precise state of the glacier, that is, advancing, static or receding, is important in forecasting streamflow. An advancing glacier will "consume" water, thereby decreasing streamflow, while a receding one will have the opposite effect. Glaciers also play an important role in the seasonal distribution of runoff. An understanding and forecasting of these conditions can play an important role in the design of dams and other structural works, and disregard of glacial regimes may lead to under- or overdesign of such projects. The value of accurate forecasting, (and in alpine areas the study of glaciers is one component) is difficult to quantify; however, the benefits are large as witnessed by the fact that for a two-year period, B.C. Hydro and Power Authority estimated that 5.8 megawatt hours of additional power, with an annual value of $10.9 million, could have been generated using more accurate forecasting.

Initiatives Associated with Northern and Alpine Environments: The problems of Arctic water resources are poorly understood. In view of the anticipated development of Canada's North, much more emphasis needs to be placed on this branch of science. It is important to recognize that the water resources of this area are largely unmeasured and will require much more expenditure on fact-finding and basic research than do comparable resources in the southern parts of the country. There is little in the way of information on the payoffs from basic research and data collection, but studies suggest that benefit-cost ratios are quite high. For example, a recently completed independent study of hydrometric data collection suggests a benefit-cost ratio in the order of 9:1.

From this general point, several areas of research and data collection can be enumerated. On the theoretical plane, basic models on the relationships between water flows and permafrost need to be developed. Such models are required to assist in solving water supply problems such as the location and sustained flow of springs, river bed and slope stability, and local problems such as the stability of buried pipelines, pavements and foundations. Attention must also be given to collecting data required for the development of theoretical models. Examples of such data are infiltration rates of water through different types of materials, ground water storage and flow rates and routes of water through the ground. Meteorological data (evaporation and transpiration data) and runoff measurements are also required.

The role of ground water in the North is very important both in understanding the hydrologic cycle and in supplying communities with reliable water supplies. Yet the occurrence of permafrost has prevented analysis of ground water flow systems by conventional methods used in temperate climates. It is recognized that permafrost may act as an impermeable or virtually impermeable barrier to ground water movement. Also, the effect of seasonal freezing and thawing in the active layer of permafrost in restricting recharge and in confining water within ice mounds and the like, is imperfectly understood. The returns from research in this area are related to the correct design of pipelines and roads. For instance, pipeline crossing of streams and icings induced by the burial of heated pipelines are some important applications that depend on knowledge of ground water flow systems. Also, pipeline crossings could be studied to determine the optimum timing of construction in order not to damage the underlying permafrost layer.

An important aspect of alpine hydrology requiring research is that of flood hazards arising from glacier dammed lakes, that is, when drainage channels within or adjacent to a glacier become stopped-up, causing the formation of large lakes within or behind the glacier. These should be studied by compiling and analyzing hydrological, glaciological, historical and other pertinent data before planning highways, pipelines and other economic improvements in downstream areas. This subject is particularly important along the Alaska Panhandle boundary and the Alcan Highway.

In view of the anticipated development in the North and the role played by glaciers in regulating water supplies, a greater understanding of the hydrology of northern and alpine environments is essential. Without such basic knowledge, development will take place in fashions detrimental to the environment and at greater social cost than necessary.

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Water Quality

The water quality aspect of water management is as important as, if not more important than, the water supply dimension. Recent public opinion surveys show that environmental quality still ranks high on the list of public concerns, with water quality being an important dimension of this concern. Economic damages resulting from water pollution are very difficult to measure, largely because the effects of pollution are not usually discussed in economic terms, and because comprehensive statistics have not been collected on this subject. Individual water users may be able to estimate pollution damages for their own particular use, but little effort has been placed on integrating these into provincial or national estimates.

One of the few Canadian studies on the economic damages due to water pollution, carried out in 1973-74, found that damages were diffused among a very large number of individual water users. Tangible damages were defined as those which can be reflected in market transactions. An example would be the extra costs incurred by municipal utilities forced to treat public water supplies beyond the chlorination level. The study estimated that the total of all tangible damages fell in the $40 to $70 million range annually. By 1980, this estimate could well be in excess of $100 million. Intangible damages are those deemed unmeasurable using current methodologies. Examples are the health effects of elevated dissolved solids levels and the aesthetic deterioration caused by poor water quality. The report concluded that intangible damages were at least as expensive as the tangible ones, raising the total estimate of damages due to water pollution to at least $200 million in terms of 1980 dollars. This is thought to be a conservative estimate.

The following sections examine the water quality problem by first describing the economic nature of the problem and then the sources and effects of five pollutant categories: nutrients, waste heat, toxic substances, nuclear materials and long range transport of air pollutants. These categories do not cover all classes of pollutants, for example, oxygen demanding wastes and dissolved solids are not included. However, the selected categories of wastes are thought to cover the areas having the most scope for economic initiatives. Most of the initiatives outlined are aimed at damage avoidance or improving water quality, all the while promoting the establishment of economic activities.

The Economic Nature of Water Pollution Problems and Opportunities

Before describing the problems and opportunities of water quality management in detail, it is valuable to examine the economic dimension of the water pollution problem. In the economies of Western societies, the market plays a key role in resource use and the allocation of goods and service. As outlined earlier, water has traditionally been considered a free good, with no economic price attached to its use. In terms of water pollution, the ability of water to assimilate and carry away wastes has been costless to industry, municipalities, agricultural concerns and the like. Because it was free, the waste assimilation and transportation properties of water bodies have been used in preference to those involving costs to the individual plants, such as in-plant treatment of waste streams. Such behaviour is rational from the viewpoint of the private polluter, even though the social costs of such overuse often exceed any private advantages gained.

Opportunities: Economics suggest that a primary instrument in achieving adequate pollution control in social terms must be the forces of the market. The economic dimensions of water quality programs have largely been ignored in the past. Economic analysis has tended to focus on the costs of pollution control and financial aspects of implementation, rather than assessment of social costs of pollution and the most efficient (i.e. least cost) solutions to the problems. Economic studies have demonstrated consistently and conclusively that pollution control is achieved most efficiently when the polluter bears the cost of adjustment to meet pollution controls and passes these costs along to his customers.

Although this theoretical position should be tempered over the short term by international circumstances, local employment conditions and other considerations, it follows that a price placed on water use for waste assimilation should be one of the central tools in water quality control. All levels of government should consider the use of economic instruments, such as effluent discharge fees, as a useful adjunct to existing water pollution programs. Proof that economic tools can be effective is provided by the use of an industrial effluent discharge fee in the City of Winnipeg. All attempts to control industrial discharges failed in that city until the effluent discharge fee was employed, and this achieved immediate and permanent lowering of pollution loadings from industrial plants. The economic benefits of such a thrust relate to achieving environmental protection at minimum social cost.

i. Nutrients

Nutrients refer to those elements which promote the growth and development of aquatic plants. The two nutrients of most concern, phosphates and nitrates, are thought to be mainly responsible for the premature aging of lakes through the process of eutrophication.

The effect of nutrients on receiving waters is accelerated eutrophication, manifested by the growth of algae and aquatic weeds. The results of such growth are taste and odour control problems for municipal water supplies and certain types of food processing, clogging of water intake facilities and aesthetic damages to the recreation sector.

Sources and Effects of Nutrients: Sources of nutrients include municipal sewage, especially in an untreated form, industrial outfalls and agricultural runoff. Canada has made rapid strides with respect to municipal waste treatment. Nutrient control has been approached in two principal ways, by limiting the amount of phosphate in cleaning compounds to 5% (P_2O_5) by weight, and by encouraging the installation of phosphorus removal (tertiary treatment) facilities in sensitive areas such as in the Great Lakes and the Okanagan basin. By 1980, 210 treatment facilities for phosphorus removal were in use principally in Ontario; prior to 1970, there were none. Phosphate regulations have reduced pre-regulation levels of detergent phosphates by 80%, from 26 000 000 kg to 5 000 000 kg per annum. With respect to agriculture, feedlot- and field runoff constitute the two principal nutrient sources. The use of fertilizers has increased at a rapid 7.3% annual rate since 1961, and by 1980, the amount of fertilizer sold in Canada rose to some 4.4 million tonnes. The control of runoff is a very difficult problem because most fields drain directly into watercourses and thus are not concentrated into a central location suitable for treatment.

An especially serious problem in Canada at the present time is that of Eurasian milfoil, an aquatic weed which is proving exceptionally difficult to eradicate. Unknown in Canada before 1970, the initial source of this weed is thought to be aquarium plants discarded after use. The two areas in Canada most seriously affected are the Trent-Severn waterway of Ontario and the Okanagan Lakes of British Columbia. In the former, some 12 000 to 20 000 ha of water area are affected, compared with only 600 ha in the latter. The annual damages to recreational interests have been estimated at $100 million. Eurasian milfoil feeds partly on nutrients in sewage outfalls, and also acts as its own fertilizer. When it dies during the winter, it sinks to the lake bottom where it fertilizes spores which have fallen from the plant.

Initiatives Arising from Nutrient Control: Even though they are non-toxic, nutrient-induced effects still are serious in terms of eliminating uses which could normally be made of a water course. Opportunities relate to the reduction of these damages. With the exception of Ontario, phosphorus removal from municipal wastewater is uncommon in Canada. Being the principal means of reducing nutrient loadings from municipal sewage treatment plants, this form of advanced treatment should be encouraged for areas in Canada where nutrients have caused problems. To control taste and odour problems, advanced water system treatment may also be necessary.

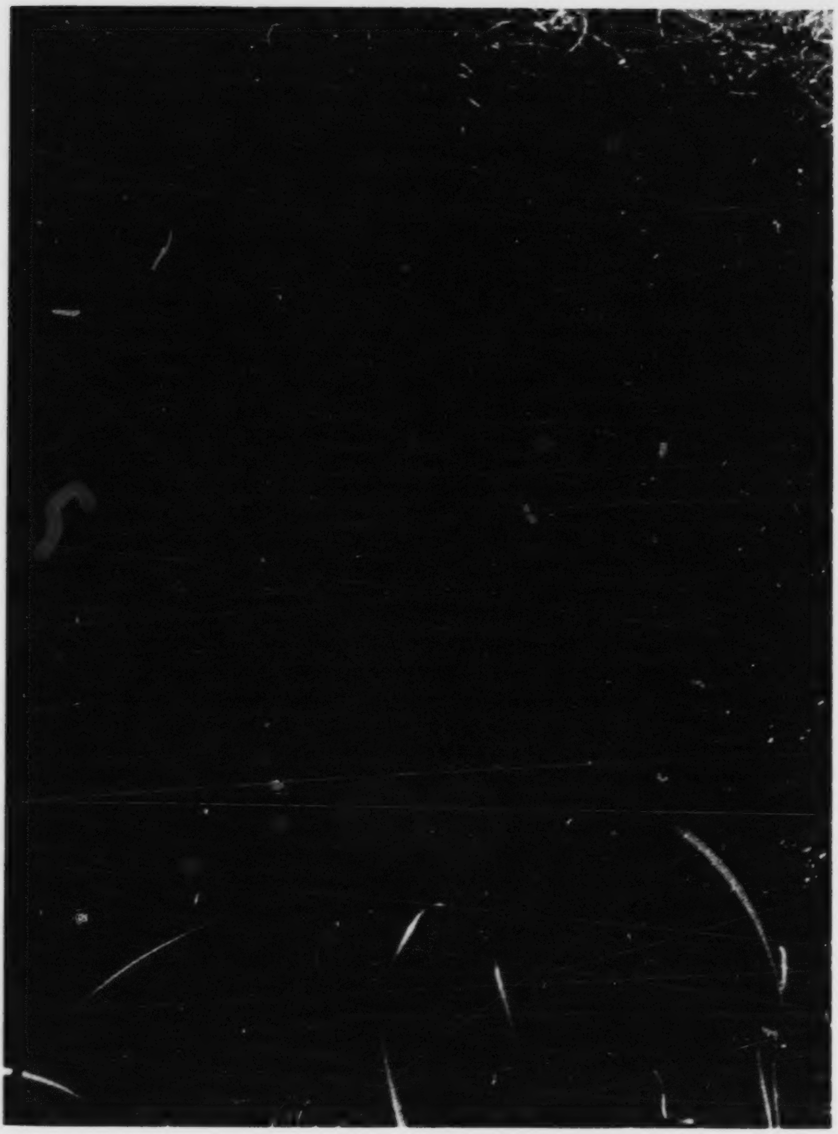
With respect to the Eurasian milfoil problem, research is aimed at eradication of the weed, using both biological and mechanical/chemical methods. An extensive monitoring program is needed to determine the environmental impact of the weed growth. An additional control measure is import prohibition of Eurasian milfoil and other plants with a similar nuisance potential.

ii. Waste Heat

Temperature is the condition of a body which determines the transfer of heat to or from other bodies. It is one of the most important water quality characteristics for aquatic life for it determines which species may be present; activates the hatching of young and regulates their growth, activity and development; and causes death when the water becomes too hot or too cold.

The total peak thermal input to Canadian fresh and tidal waters is expected to increase from 6.025 x 10^{10} BTU/hr in 1970 to 136.7 x 10^{10} BTU/hr in the year 2000. Approximately 80% of heat rejection to the environment in Canada is contributed by electrical power production facilities.

Issues Associated with Waste Heat: Although water bodies have a natural temperature range, such ranges are usually not damaging, as aquatic life and human use of the water have tended to adjust accordingly. The discharge of waste heat from industry or power utilities may, however, cause serious problems. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic material. The decay rate increases with temperature, reaching a maximum at about 30°C. Thus dissolved oxygen decreases with increases in temperature. Fish sensitivity to rising temperatures varies with the heating rate, size and physical condition of the individual species. High temperature, because it causes physiological stress, may reduce swimming speed significantly and cause starvation due to inability to capture food. Also, dissolved oxygen depletion may cause suffocation. Toxic effects also increase with temperature, posing an additional threat. In addition to damages to fish



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stocks, elevated temperatures pose taste and odour problems for municipal and industrial water supplies. This problem is especially critical during low flow periods in summer. The decay rate is substantially increased in the heated, slow-moving water, and eventually can impart a taste to the water which is exceptionally difficult to remove. This problem is exacerbated by waste heat discharges. Finally, the cooling properties of water are reduced by upstream waste heat discharge. Increased pumping costs ensue for downstream users because larger amounts of water are required in cooling operations.

Initiatives Associated with Waste Heat Management: The discharge of waste heat constitutes a loss of valuable energy resources and, as such, is a cost to society, even though it might currently be the cheapest method of handling the problem from a private viewpoint. Up to 70% of the heat in thermal power plants is simply discharged back into the environment after use. A significant opportunity for the future is the concept of district heating, using waste heat from thermal power plants or other large industrial users. These sources could support a large number of residences or smaller industries with hot water heating. Such a scheme would not only reduce the environmental problems of waste heat, but would also lower energy demands.

Associated with this initiative is the use of the heated water for agricultural purposes. This initiative has already proven successful in Ontario where the heating of greenhouses has lengthened the growing season for vegetable crops. This initiative could be extended to other areas. Both of these initiatives call for expanded research into new designs for conveying heated water to residences and agricultural establishments, and finding new applications for this recycling concept. Also, a program of financial assistance would promote extension of this idea, while wide dissemination of the findings from research and economic analyses would help to encourage private industry to find new applications for waste heat.

Another initiative is the use of a ground water heat pump. Building heating is provided in the winter by extracting low grade geothermal energy from a ground water aquifer. By simply reversing the refrigeration cycle the heat pump can be used as an air conditioning system during the summer period. The heat is returned to the aquifer for reuse the following winter.

The economic aspects of waste heat reuse have been poorly researched in Canada to date. However, the potential benefits seem quite significant. For example, in Sweden, which has a climate similar to Canada's, some cities use waste heat from thermal power plants to supply up to 80% of their heating requirements. In terms of horticulture, Canada imports more than one billion dollars worth of fruits, nuts and vegetables annually. The possibility of import substitution exists based upon greenhouse agriculture using waste heat. The economics of such an industry needs analysis before concrete programs could be initiated.

The use of waste heat to extend navigation seasons on the Great Lakes – St. Lawrence Seaway is theoretically possible. However, feasibility studies have presented no detailed cost-benefit analyses, though a general review indicates that problems and concomitant costs would outweigh benefits. In view of the annually increasing net losses incurred in the Seaway operation, any further large scale, high cost alteration would increase those losses in the short term. Thus, stronger and more tangible indicators will be necessary to prove that returns will be worthwhile in the long term. A major problem is that although navigation season extension would use large amounts of waste heat in winter, there is no adequate alternative use in summertime.

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iii. Toxic Substances

This class of substances covers a wide variety of materials, some of which may occur naturally and others which are manmade. The term toxic is a relative one, because the effects of any chemical or mixture depends not only on its composition and basic properties, but also on dosage, route and conditions of exposure, susceptibility of the organism exposed and other factors. As used here, toxic substances refer to those chemical substances which, when released to the environment, or thereafter, if chemically transformed through combination or otherwise, could pose a threat to natural ecosystems or to human health and well-being.

Effects of Toxic Substances: Toxic materials vary widely in their effects. Some are acutely toxic, damaging or killing various life forms, or, on the other hand, being highly selective in their effects. Acute toxicity may result from a low level of a highly toxic substance, or a high level of a less toxic material. Often, acute toxicity appears as a slug, or a high concentration, resulting from a dump or a stream of toxic discharge, accidental or otherwise. Some materials produce chronic toxicity which may require substantial periods of time to be noticed. This form of toxicity is frequently observed as reproductive failure in the affected organism. Slowly, toxic materials may be more deleterious to a particular developmental stage than to an adult organism. Still other materials are sub-lethal in their effects, and may for example, impart unpleasant flavours to fish. Such effects can be as bad as acute toxicity in destroying a recreational fishery.

Lead is one of the most common elements on earth. It was at one time an additive to almost all gasoline although, since 1975, this use has gradually been decreasing. However, other uses of lead including batteries and battery oxides and chemicals have been expanding. From a production of 72 thousand tonnes in 1961, lead production expanded to 274 000 tonnes in 1980. It is known that lead accumulates in the skeletal structure of man and animals. Low level affects can cause symptoms such as anemia, headaches, sterility or the birth of brain-deformed babies. Higher concentrations can cause convulsions, coma, blindness, mental retardation and even death.

Cadmium is used largely in the electroplating industry and also in the manufacture of solder. In 1980, some 1 269 000 kg of cadmium were produced in Canada for all uses. Cadmium is implicated in causing cardiovascular disease and hypertension. In addition, it interferes with proper zinc and copper metabolism.

Many other toxic substances, which may contaminate water supplies, are under active investigation by Environment Canada. Among these are mercury, PCBs, mirex, chlorofluorocarbons and pesticides. The toxic effects of these substances vary widely, depending upon the chemical involved and the type of organism exposed.

Pesticides include a large number of chemical compounds used to control pests which are detrimental to man and his environment. Most pesticides are members of the organochlorine category of chemicals, produced by chlorinating organic compounds in a wide variety of forms. All such compounds show great affinity for fatty tissues of animals and are extremely slow to decompose. Over 900 pesticidal chemicals have been developed and many times that number of preparations are available for use.

Pesticides consist of several types of materials, among them insecticides, herbicides and rodenticides. From 1961 to 1975, the sales of pest control products in Canada experienced a rapid 6.9% real growth rate, reaching $103.6 million in 1975. Assuming the continuation of this trend, sales should be $144.6 million in 1980. Agriculture accounted for 87% of total sales of pest control products in 1975 and, of this amount, 56% was spent on insecticides and herbicides. The growth rate in these two types of pesticides was 8.5% between 1961 and 1975, and the annual cost should reach about $100 million in 1980. The benefits of pesticide use are enormous. They take the form of increased crop yields – up about 300% since intensive pesticide use began – and significant control of insect-borne diseases such as malaria.

Yet, the use of pesticides has proven to be a mixed blessing for, along with their benefits has come a controversy over their harmful environmental effects. From the water management viewpoint this problem can be seen as one of pesticide residues being transported in watercourses and taken up by fish, wildlife and humans. Pesticides are not water soluble, but are soluble in animal fatty tissue. For this reason, pesticide residues accumulate in animal and fish life, and tend to be magnified, or concentrated to higher levels further up the food chain. For example, DDT, once one of the most common pesticides but now a restricted product with a very limited use pattern in Canada, evaporates directly to the atmosphere or clings to water droplets. Since it is soluble in fats, even if the concentration in the environment is low, organisms with a high fat or oil content will readily absorb more and more DDT. Moreover, DDT is thought to have been responsible for reproductive failure in several bird species (e.g. peregrine falcons) because, through interference in the calcification process, egg shells became thinner and more fragile. DDT and other pesticides may also interfere with the photosynthetic process and reduce the growth of marine plankton. From the viewpoint of public health, some preliminary research evidence shows at least a correlation between high DDT levels and problems such as cerebral hemorrhage, cirrhosis, infertility and various cancers.

Initiatives Associated with Toxic Substances: The use of all toxic substances must be regulated to ensure that only safe amounts enter the environment. The case made earlier for the use of economic instruments such as effluent discharge fees also applies to toxic substances. In Canada, the regulatory approach is employed by means of the Environmental Contaminants Act, administered by Environment Canada, and by similar provincial acts. At the federal level, a Toxic Chemicals Management Program has recently been established to coordinate related departmental programs.

In water management, programs dealing with toxic substances seem limited to protection against damages, and it is doubtful that the economic benefits of such programs can be quantified adequately. The first initiative relates to improved monitoring of toxic flows to receiving waters. While some substances may be sub-lethal through a wide band of concentrations, some scientists contend that thresholds exist beyond which toxicity becomes widespread and extremely damaging. Improved monitoring will help to ensure that such thresholds are not reached or exceeded. The second and third initiatives are research-oriented. There is a need to develop better ways of treating toxic waste streams.

One set of possibilities concentrates on waste treatment prior to the discharge of water-borne wastes. The other set concentrates on water treatment prior to use. Both of these research initiatives can be promoted through government funding assistance. In addition to developing these treatment initiatives, research to find alternatives for the use of toxic substances should be encouraged.

Several opportunities arise in pesticide management with respect to restoring damaged or forgone uses. The first relates to use of minimal amounts of the material. Threat of pest invasion or adaptation to existing dosages may result in increased use of the pesticide. Careful monitoring of pest populations would make possible the minimization of pesticide use. Selective spraying and the monitoring of pesticide levels in streams are other elements in ensuring minimal dosages.

Government agencies normally increase their stream monitoring activity in any spraying area to determine impacts on ambient water quality. The aim is to make recommendations as to dosages applied to minimize the water quality effects, while maintaining the effectiveness of the spraying program. Based on the monitoring and impact determinations, the benefits and costs of the spraying program can be assessed to determine whether the program is economic in terms of social welfare.

A second initiative relates to modifying equipment to ensure more efficient spraying. A study in the United States showed that, even under ideal conditions, only 17% of pesticide application from aerial spraying was at the proper rate. Alternative forms of application have been shown to be effective. Other initiatives include modification of pesticide formulation, and the use of non-chemical methods such as the introduction of predators.

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iv. Nuclear Materials

The development of nuclear energy has presented society with one of its most serious dilemmas. On the one hand, Canada's uranium resources offer a large and attractive source of electric energy. On the other hand, nuclear materials carry with them significant potential health and environmental hazards which will require an extremely high level of care. The most severe conflicts will probably occur in Ontario, the province with the highest consumption of electric energy, a scarcity of fossil fuel resources and a substantial portion of Canada's proven uranium reserves.

In 1975, the electrical demand in Ontario totalled 82 000 GWh. By the year 2000 this demand is expected to grow to 244 000 GWh, an annual increase rate of 4.5%. This demand will require a total generating capacity of about 50 000 MW. According to Ontario Hydro, about 50% of this total capacity will be satisfied by nuclear plants compared to 13% in 1975. Recent pronouncements by Ontario have confirmed this commitment to emphasize nuclear generating facilities.

Issues Associated with Nuclear Wastes: Public health concerns dominate the problems associated with nuclear contamination of water supplies. Most scientists believe that even the smallest dose of radiation may cause damage to exposed organisms. Genetic effects also result from exposure to radiation. From small doses, such effects may be extremely subtle and materialize as slight increases only. However, genetic effects become more obvious with exposure to higher dosages.

In terms of the water environment, four particular problem areas are apparent. The first is the ground water system in the area of uranium mines. Mining may re-align underground channels, and bring naturally occurring radioactive contaminants to the surface. Also, 80% of the mined uranium ore is eventually discarded as waste. This material is still radioactive, and may be leached from the waste and thereby contaminate either surface water or ground water. The second problem area is in the vicinity of power plants themselves. The escape of low-level radiation in the form of tritium and minor amounts of other fission products is very difficult to prevent. Accidental escapes resulting from plant emergencies may also contaminate water resources. A third problem is the generation of waste heat, which was discussed earlier. Lastly, nuclear wastes require storage over periods of thousands of years. There is evidence of ground water contamination at earlier dump sites (for example, near Chalk River), and the threat of eventual leakage to surface waters. This problem points up the need for disposal sites which will be stable and have no impact on ground water systems.

Initiatives Associated with Nuclear Materials: The benefits of nuclear technology in supplying electrical energy are clear, and are a major part of Canada's goal of long-term energy self-sufficiency, particularly in Ontario. The future points to a rapid expansion in the number of nuclear generating plants in Ontario. All of the water quality-based initiatives outlined below are oriented to damage avoidance, and are difficult to relate to economic gain.

The first initiative relates to the need to evaluate potential damages arising from waterborne radiation. Studies in this area are difficult to find in Canada, and yet, to know the damages which might be incurred from nuclear expansion and to have an estimate of water-based damages seems essential for effective management. There is an urgent need to develop evaluation methodologies in this area.

Increased monitoring is a second initiative related to nuclear expansion. This is required to establish baseline and trend data on radioactive materials in the water. This initiative is especially important in the vicinity of proposed plant sites, mines and disposal sites, and involves the monitoring of both surface water and ground water.

A third initiative concerns the research and development of technologies for the immobilization and safe disposal of nuclear fuel wastes. Responsibility for this research and development rests with Atomic Energy of Canada Ltd. A comprehensive 10-year program including both field and laboratory studies is under way to assess the feasibility of deep undergound rock formations. Several federal and provincial government departments, industry and the academic community are participating in the program.

Field studies at several research areas within Ontario are being carried out to investigate the hydrogeology of deep crystalline rock formations and thus the suitability of these formations as disposal sites for nuclear fuel wastes. Barring catastrophic events, the only way nuclear fuel wastes may reach the surface and the biosphere from an underground disposal vault would be by ground water circulation. Consequently, considerable effort is being focussed on the nature of ground water flow systems and their ability to transport nuclear fuel wastes in deep crystalline rock formations.

v. Long Range Transport of Air Pollutants (LRTAP)

LRTAP is the most recent of a long list of environmental problems which have confronted society since the late 1960s. Commonly called the acid rain problem, the LRTAP problem exemplifies the interconnections between various environmental resources, in this case air and water.

Problems Associated with LRTAP: Acid rain occurs when sulphur oxides and nitrogen oxides are released to the atmosphere and react with water vapour to produce acids. The most significant contributors of sulphur oxides are the non-ferrous smelters in Ontario and coal-burning power plants in the United States. International Nickel in Sudbury, Ontario, which may discharge up to 2 500 tonnes of sulphur dioxide daily into the atmosphere, accounts for 1% of the estimated SO_2 emissions in the world. Other Canadian sources are Noranda smelting operations in the Rouyn-Noranda and Murdochville areas of Quebec, the non-ferrous smelters in Flin Flon and Thompson, Manitoba, and smaller operations throughout the Great Lakes-St. Lawrence area. In terms of the continental picture, 28.9 million tonnes annually of SO_2 enter the North American environment, 24.1 million from the United States and 4.8 million from Canada; statistics for nitrogen oxides are 21.1 million tonnes in total, 19.3 million from the United States and 1.8 million from Canada (1980 data).

The acid rain problem truly affects all aspects of environmental management. In the case of water, the problem is manifested by increased acidity in lakes and rivers. Particularly hard hit are the lakes of the Precambrian Shield, where the granitic rock, overburden and sediments often lack the buffering capability which keep the problem in check. The effects on fish and wildlife are devastating, with complete fish kills being the long-term result. In the Sudbury area, 140 lakes have been found devoid of aquatic life, and it is estimated that some 48 000 more are showing tendencies toward increasing acidification. The sensitive species of fish (e.g. trout) are the first to be decimated by rising acidity. Other effects of acid rain include damage to the forest resource and interference with the nitrogen cycle in soil.

In terms of economics, the costs and benefits of controlling acid rain have been incompletely quantified; in fact, no consistent and logical approach to the economic aspects of the problem has yet been attempted. Thus, for economic impacts, conclusions must be inferred from indirect data. The activity most affected is recreation and tourism. During 1976, the principal recreational areas in Ontario, the ones most affected by acid rain, generated 73 000 person-years of employment, with total tourist related income of $1.2 billion. Province-wide, the tourist industry is the second largest, accounting for 470 thousand person-years of employment and $5 billion. The costs of bringing the problem under control are truly staggering, but probably justified. In Canada, total annual costs have been reliably estimated at $500 to $700 million over a generation. The comparable costs in the U.S. would fall between $4 and $5 billion. Although a formal benefit-cost analysis has never been carried out, it appears that these costs would be justifiable on the basis of protecting the tourism and recreation industry alone.

Initiatives Associated with LRTAP: Water management initiatives with economic benefits are numerous in the area of acid rain. As outlined above, the benefits of controlling this problem appear to justify the large costs involved. However, this conclusion needs to be verified by detailed analyses. Initially, this work should concentrate on developing damage functions to relate economic damages to pollutant levels, and cost functions to define the cost of pollutant control for various levels of abatement.

A second initiative relates to increased research into the water quality problems involved and in establishing baseline information against which to assess future improvements. Such information is required to assess the effectiveness of programs in this area. Also associated with this initiative is the need to expand monitoring networks to obtain trend information on the acid rain problem. An assessment of the neutralizing capabilities of the overburden-sediment-ground water system must be included to determine the influence on overall water quality.

The area of discovering alternatives to discharging sulphur dioxide offers a third major initiative associated with the LRTAP problem. One example is found in the manufacture of sulphuric acid and combination of this with phosphate to produce fertilizer. Large deposits of phosphate rock are located in northern Ontario, and use of this resource in concert with the rich potential source of sulphuric acid in Sudbury seems worth investigating, in light of the rising world demand for fertilizer. The economic studies involved would be on a Canada-wide basis in terms of competing with other fertilizer producing areas. A second such area would be to develop markets for sulphur as a building material. Initial studies have shown the viability of sulphur as a major constituent in highway paving.

The last initiative relates to managerial instruments for controlling acid rain problems. Specifically, the concept of effluent discharge fees might be examined to assess its feasibility in controlling emissions of SO_2 and other pollutants responsible for the problems of acid rain. Other economic measures such as tax concessions, subsidies, etc., could also be examined comprehensively in seeking solutions to this problem. The thrust of these economic examinations would be to achieve efficient solutions in the economic sense. It is important that concrete action be undertaken in this area to complement scientific and technical work now under way.

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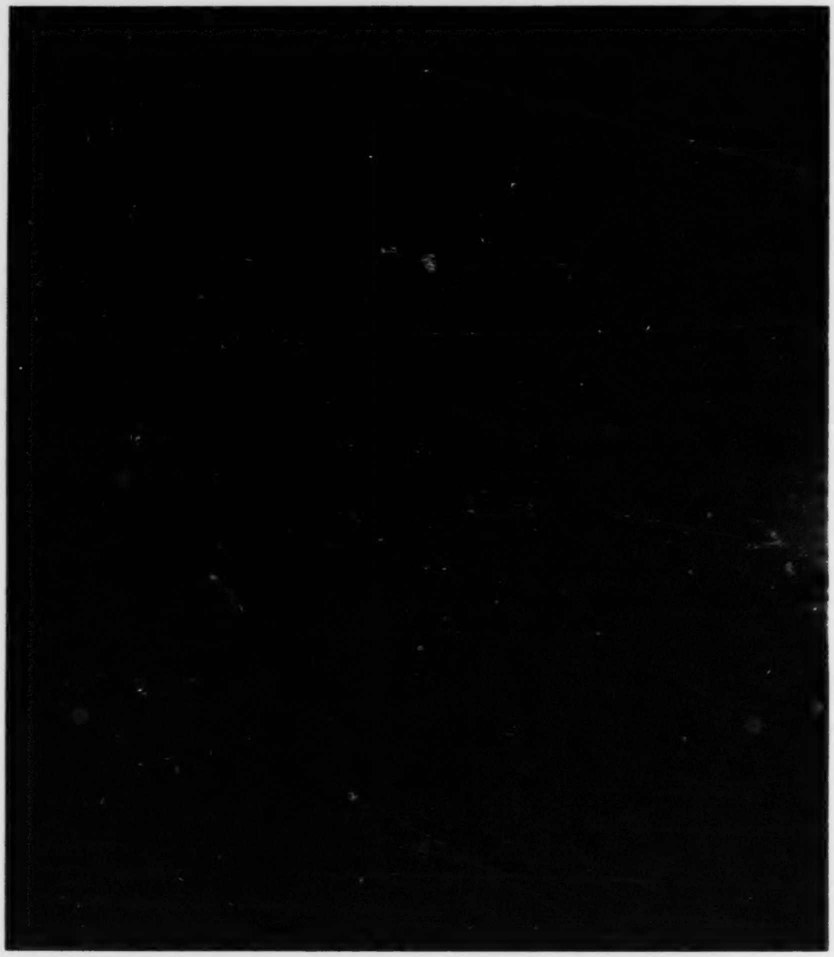

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In the early phases of Canada's history, concentrations of population and economic activity were limited. Even in the built-up areas, demands on the water resource were small enough to ensure that all uses were satisfied in terms of both amount and quality. But population growth, urbanization, industrial expansion and technological development have modified this earlier situation to a significant degree. Today the largest withdrawals are made by thermal generation stations for cooling purposes. Following closely in magnitude are the industrial uses – manufacturing and mining. Other uses, such as municipal and rural, and agriculture, have not grown as rapidly. With this shifting of sectoral importance and with growth in all sectors have come many conflicts between water uses. The solution to such conflicts is a major aim of water management in Canada today.

This chapter updates to 1980 the estimates of water use throughout Canada published in earlier editions of the Canada Water Year Book and introduces corresponding values of water consumption. Similar estimates for 1980 are presented for the Great Lakes basin together with low, high and "most likely" projections of water consumption in the years 2000 and 2035.

For some considerable time, several water demand studies have been under way in the prairie region and it was intended that this Year Book should discuss the findings of one referred to as the Prairie Provinces Water Demand Study. At this writing, however, the findings of that study are still being compiled and the information that follows merely discusses the need for the water demand study and why it should be seen as an important tool for better management of existing water supplies.

Depending upon the time of year and the chosen location in Canada, the amount of water available may range all the way from a flood situation to one of drought.

Recent events involving both floods and droughts in Canada are discussed in this chapter with emphasis on their impacts on Canadians.

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At the simplest level of providing drinking water or driving a hydroelectric turbine or carrying barges in a canal, water uses are single-purpose. Increasingly, however, such uses cannot be considered in isolation from other uses. The source of drinking water also meets a firefighting need and contributes to waste disposal; a storage reservoir for electric power generation can also provide for recreation and irrigation needs; a ground water aquifer which is used for irrigation can also serve as a water supply for mining or manufacturing. The technology for gaining multiple benefits from a water body has expanded rapidly, and has changed the capacity to use, reuse and purify available supplies.

The classification of water uses – withdrawal and non-withdrawal – and their further division into consumptive or non-consumptive uses, indicate the basic differences among the uses.

As their titles imply, the withdrawal uses remove water from its natural course while non-withdrawal uses do not. Withdrawal uses are primarily for domestic, industrial, steam-electric power and agricultural (irrigation and livestock) purposes. Non-withdrawal uses include hydroelectric power, navigation, recreation, and fish and wildlife uses.

For withdrawal uses, all or part of the water withdrawn will generally be returned to the source, often at another location. Estimates of the amounts withdrawn for various uses are given in Table 3. Not so easily quantified are estimates of non-withdrawals. As a result, such estimates are not attempted here.

Withdrawal use is most commonly discussed in terms of intake and consumption. Water intake is a measure of the amount withdrawn from the natural course for a particular activity. This measure is important because it quantifies the demand imposed by that particular activity on the water resources at that given location. Usually, however, most of the water withdrawn is returned to the watercourse. Thus, in an overall supply-demand balance for that area, water intake is not the salient factor. What is important is the amount of water not returned to the source, that is, the amount consumed. Estimates of consumption also are given in Table 3.

A process which reduces water withdrawals is water recirculation. Recirculated water either is used more than once in a given process or it may be used once and then recycled to another process. Recirculation is most common in certain industrial operations such as pulp and paper production, petroleum refining and steel making. The contribution made by recirculation to water use in Canada is indicated in Table 3.

Withdrawal Uses: Withdrawal uses of water clearly establish water's importance in the Canadian economy. Table 3 contains estimates of the various withdrawal uses for 1980. In the table are statistics on both the amounts withdrawn and the corresponding amounts consumed (and therefore not available for further use). The table reveals that, in 1980, 111.7 billion litres per day (bLd) of water were withdrawn for all uses in Canada, of which 9.2 bLd or 8.2% was consumed.

Although the various uses are discussed in detail in the chapter which follows, several points should be made here in summary. The largest withdrawals, some 43% of the Canadian total, are made by thermal generating stations for cooling purposes. The 5.5% annual growth rate in water needs in the thermal industry is also the highest growth rate of all the withdrawal users, raising this industry's water needs for the year 2000 to some 143 bLd from 48 bLd in 1980. The high growth rate is attributable to increasing adoption of nuclear technology, particularly in Ontario. Nuclear plants use roughly twice as much water as conventional thermal plants. Since thermal generating stations require large continuous flows, such plants are less suitable for regions of scarce water supply.

In 1980, an estimated 173 900 mLd of freshwater, equivalent to some 7 100 litres per person per day, were used to meet the gross demand for all water uses in Canada. The actual water withdrawals are shown below by region and principal use.

Recirculation allows some of the water to be used over and over again. Recirculation in manufacturing and mining has made it possible to extend the 38 156 mLd and 4 443 mLd to meet demands of 88 000 mLd and 16 800 mLd respectively, and, in terms of all uses in Canada, the 111 705 mLd has been stretched to meet a demand of 173 900 mLd.

	Municipal and Rural	Manufacturing	Mining	Agriculture	Thermal	Total
Withdrawal						
Atlantic	1 443	4 078	677	68	8 627	14 893
Quebec	4 510	7 900	337	84	2 744	15 575
Ontario	3 615	19 676	704	698	30 685	55 378
Prairie Provinces	1 739	860	2 339	5 878	5 557	16 373
British Columbia	1 076	5 642	277	1 568	787	9 350
Yukon & NWT	27	—	109	—	—	136
	12 410	**38 156**	**4 443**	**8 296**	**48 400**	**111 705**
Consumption						
Atlantic	155	118	82	68	65	488
Quebec	637	306	45	83	21	1 092
Ontario	522	762	46	580	230	2 140
Prairie Provinces	470	154	465	2 941	42	4 072
British Columbia	282	227	109	737	6	1 361
Yukon & NWT	9	—	45	—	—	54
	2 075	**1 567**	**792**	**4 409**	**364**	**9 207**

The largest water consumer is agriculture, which consumed 4.4 bLd in 1980 (48% of all consumption); this figure is projected to grow to 6.6 bLd by the year 2000. Consumption in irrigation is large, despite the fact that agriculture accounted for only 7% of total withdrawals in 1980. Because irrigation is concentrated in western Canada, continued development of this type of agriculture will cause excessive strains on the region's water resources, with corresponding large expenditures for water development.

Mining (metals and oils) is also a relatively high consumer of water because a significant amount of surface water is used in deep well injection in the oil and gas extraction process. The quantity of water used for this purpose will undoubtedly increase as more oil and gas extraction occurs. Since much of the activity occurs in the drier areas of the country, it can be expected to have a significant effect on water availability.

Manufacturing, the second largest in terms of total withdrawals, has a relatively low consumption rate. Thermal plants also have a low water consumption rate. With such a large withdrawal use, certain industries may be unsuited to regions of wide water supply variation. Recirculation technology may be one solution to this problem, as it would decrease water withdrawals significantly. Consumption does not appear to be a problem in terms of locating manufacturing in water-short regions.

Municipal water use is projected to grow in line with the population growth rate, and may cause problems in water-short areas. Water demand management through pricing and other policies are looked upon as possible solutions to municipal water shortages in the future.

Non-withdrawal Uses: The non-withdrawal users are often more important than the withdrawal users in establishing the role of water in the Canadian economy. For these users, water is not merely one input, but the most important input to production or enjoyment. For example, navigation would cease to exist without water, as would hydroelectric generation. Recreation would be vastly altered in the absence of water. Fish and wildlife areas rely upon adequate supplies of high quality water but the precise use of water for non-withdrawal uses is difficult to quantify. Concepts such as user days, values of fish catches or animal pelts, tonnages shipped and power production, are important in dealing with the various non-withdrawal uses but, are difficult to compare one with the other. This means that quantification is a somewhat indirect exercise compared with the relative neatness of the withdrawal uses. Nevertheless, a few statistics will serve to emphasize the importance of these sectors of the economy and indirectly, the importance of water.

Water, in its natural setting, is a principal attraction of Canada's 28 national and 500 provincial parks. Taken together, these parks cover a total area of 330 000 km^2 and, in 1980, received some 73 million visitors. But parks are not the only attraction. Elsewhere in the recreation sector, the visitor growth rate is expected to be just under four times the population growth rate, reflecting growing incomes and an increase in leisure time. Sports fishing is an important recreational activity of four to five million Canadians and visitors. Commercial fishing is a major employment sector on both Atlantic and Pacific coasts of Canada, with an estimated labour force of between 20 000 and 25 000. Navigation is also very important for Canada, with its large trade flows. Currently, about 280 million tonnes of cargo are handled at Canadian ports, of which 65 million tonnes, or 23%, are handled by ports along the Great Lakes.

The Great Lakes region, incorporating one of the most important inland waterways in the world, straddles the boundary between Canada and the United States and is home to about 37 000 000 persons. Its economy is basically industrial, with major contributions from forestry, agriculture, mining, commercial and sport fishing, and recreation and tourism. Not only do industries in the region benefit from the transportation and power advantages offered by the Great Lakes-St. Lawrence River system but its water supplies have been shown to be the primary reason for the region's heavy industrialization.

Because the U.S. portion of the region has a larger population and a far greater level of development, it is understandable that economic activity on the U.S. side would have a greater monetary value than that in Canada. Nevertheless, the levels of population, industrial development and agricultural production in the Canadian section make this relatively small part of Canada the most important contributor to Canada's economy. In 1974, the latest year for which complete statistics are available, the Great Lakes region in Ontario accounted for about 51% of the total value of shipments by the Canadian manufacturing sector. The region also is the primary focus of the iron and steel industry in North America, accounting for 40% of the U.S. production and 80% of the Canadian output. And there are high national proportions of other industries in the basin, including chemical, petroleum refining, food products, paper products, machinery, transportation equipment and fabricated metal products.

Estimates of the current and future levels of both withdrawal and consumption of water required to sustain growth in the region's economy are presented in the following paragraphs. This information was abstracted from a 1981 report prepared by the International Great Lakes Diversions and Consumptive Uses Study Board in response to an International Joint Commission Reference. The intent behind the Reference was to consider and report upon existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters, and existing diversions.

Forecasting Regional Withdrawals and Consumption

Most of the water withdrawn in the Great Lakes region is eventually returned to the system by direct discharge into lakes and streams or by infiltration into the ground water table. However, instead of being returned to its source, a portion of this water is consumed, that is, it is assimilated by animals, humans and plants, incorporated into products during industrial processes or lost from the system through evaporation or leakage during use. Although consumptive uses are the subject of interest, they have to be viewed in terms of water withdrawals with which they are intimately related and form an integral part.

Non-withdrawal uses of water such as navigation, recreation and fishing, to name only a few, do not consume water and, therefore, were not considered. The seven sectors investigated are listed in Tables 4 and 5. Of these, three sectors (manufacturing, thermal-electric and municipal consumptive uses) accounted for the major share (80%) of total consumption in the Great Lakes Region in 1980 and are expected to represent an even larger share (93%) by the year 2035.

In a sense, water consumption cannot be totally quantified when applied to a large basin because evaporation of water during use may add some quantity to the natural background precipitation and thus some portion of the consumed water could reappear within the basin. However, quantifying this small amount relative to total precipitation is presently beyond the state-of-the-art in meteorology. Thus, the principle has had to be adopted that water consumed at any point in the basin is lost to the system.

Reliable water demand forecasts relate directly to accurate economic projections. Since economic projections are difficult to make, the consequent accuracy of water demand forecasting has a certain degree of uncertainty. The collection and analysis of water use data for Canada on a systematic basis has only recently begun, and the requisite statistical series for trend analysis do not yet exist.

But simulation modelling with varying input parameters is a common approach to the problem of uncertainty. By analyzing the response of water demands to changes in

Country/Sector	Withdrawals	Consumed
CANADA		
Manufacturing	16 830	660
Municipal	2 450	390
Thermal-Electric	30 510	220
Irrigation	340	270
Rural Stock	220	220
Rural Domestic	170	100
Mining	390	—
Sub-Totals	50 900	1 900
UNITED STATES		
Manufacturing	50 910	6 190
Municipal	15 930	1 740
Thermal-Electric	68 330	2 030
Irrigation	710	580
Rural Stock	320	320
Rural Domestic	1 270	780
Mining	2 910	640
Sub-Totals	140 400	12 300
Totals (U.S. & Canada)	191 300	14 200

the underlying parameters, a range of future water uses can be developed.

In developing reasonably foreseeable future projections of withdrawals and consumptive uses, it was necessary to adopt a variety of general assumptions, based on information and advice from appropriate authorities. These assumptions related to such parameters as trends in population growth and migration, employment levels, GNP, per capita consumption, economic growth, energy use and governmental policies. Based on these assumptions, a most likely projection (MLP) was tested. However, realizing that in any long-range economic forecasting, even the most realistic of assumptions are debatable and become increasingly tenuous when applied further into the future, the sensitivity of the assumptions on the computed estimates also was tested. This was done by varying some of the more significant assumptions, within a reasonable range of possibilities, to produce alternative high and low projections and thus define a band of probable future values centered on the MLP.

Water demand forecasts have traditionally been conducted at two levels, the macro (or overall region) level and the micro (or local) level. The study from which this information was extracted was a macro level one, aimed at projecting water demands in the entire Great Lakes basin and its component sub-basins, as opposed to preparing forecasts for individual municipalities.

Uncertainties in Water Use Forecasting

Forecasting water use, as in any forecasting, is an uncertain exercise since assumptions upon which projections are based will change with time. Three principal types of uncertainties are involved: economic uncertainty, technology uncertainty, and the uncertainties in water management policy.

There are three fundamental time horizons over which economic forecasts are conventionally carried out. At the most detailed level, forecasts have a one- or two-year horizon. Even then, policy shifts, embargos, energy crises, and many other factors can influence such short-term forecasts. At the next level, the horizon is about ten years. Despite the fact that a statistical base will be employed to obtain these forecasts, the projections are viewed not as certainties, but as conditional responses to the assumptions made. At the third level of forecasting, only population or similar parameters which have some degree of regularity and normally many years of past observation, are projected, and then only on an "alternative futures" basis. More than 25 years into the future, forecasting enters the realm of guesswork. If one goes back 60 years to the early 1920s, who would have predicted the current standard of living, the status of transportation, or the intervention of World War II. The same problems are inherent in going ahead 60 years.

Technological forecasting is even more difficult than economic forecasting. Currently, energy use is posing a serious problem throughout the world. The energy crisis affects everyone economically, but one can only guess at the technological effects that it will give rise to. New methods of water use

Country/Sector	Consumption Projections					
	2000			2035		
	Low	MLP*	High	Low	MLP*	High
CANADA						
Manufacturing	1 220	1 470	1 930	3 670	4 890	11 800
Municipal	390	490	590	690	880	1 050
Thermal-Electric	510	780	1 320	1 810	3 770	6 120
Irrigation	290	320	390	510	590	730
Rural Stock	240	290	370	420	540	660
Rural Domestic	120	150	180	170	200	200
Mining	20	20	20	70	100	170
Sub-Totals	2 800	3 500	4 800	7 300	11 000	20 800
UNITED STATES						
Manufacturing	8 560	9 790	12 480	13 210	18 350	23 000
Municipal	1 830	2 150	2 940	2 370	2 940	5 380
Thermal-Electric	3 180	5 380	5 380	12 480	25 690	35 720
Irrigation	1 220	1 220	1 330	1 930	1 930	2 080
Rural Stock	320	320	340	340	340	340
Rural Domestic	810	810	810	910	910	910
Mining	810	810	810	1 130	1 130	1 130
Sub-Totals	16 700	20 500	24 100	32 300	51 300	68 600
Totals (U.S. & Canada)	19 500	24 000	28 900	39 600	62 300	89 400

* MLP – Most likely projection

in production and processing, and even new industries are certain to develop over the forecast period considered here. Because the basic economic structure has been held constant, technological uncertainty is bound to influence these forecasts in ways that are not currently evident.

Public policy too can have major effects on the forecast use of water. For example, recent studies in Canada imply that considerable new expenditure on new or expanded water supply systems will be required to meet presently foreseeable water uses on the horizon. In many cases, public expenditures will be involved. Water supply and treatment systems already comprise some of the most costly items of public expense, and will be even more costly in the future because of competing demands for capital. It therefore becomes desirable from a policy standpoint to attempt to limit water supply expenditures by curtailing demands. One method of doing so is through the use of economically-based pricing systems. If this is done, and at present it is not, these water use forecasts will be in error, particularly for municipalities and some industries.

Water Use Sectors

Seven water use sectors were considered in this study. Although only the years 1980, 2000 and 2035 are covered in the tables, recent water withdrawals and consumptive uses were determined for both 1975 and 1980, together with projections at five year intervals to 2035. Withdrawal and consumption quantities were developed in a breakdown by lake basin, nation, water use sector, and lake and non-lake categories (that is, water taken directly from the lakes or from inland sources such as tributary streams and ground water sources). These additional breakdowns are published in the main report and appendices of the International Great Lakes Diversions and Consumptive Uses Study Board.

Metered withdrawals in the Great Lakes region provide a basis from which to derive estimates of consumptive uses. As shown in Table 4, total withdrawals in 1980 were large (191 300 mLd) compared with consumptive uses (14 200 mLd). Canada accounted for about 27% of total withdrawals and about 13% of total consumption in 1980. The United States accounted for the remainder.

Table 5 summarizes the Great Lakes consumptive use forecasts for the years 2000 and 2035 in terms of the most likely projection (MLP) and the high and low projections. The table shows that water consumption is projected to increase in all sectors, with the largest increases showing in the totals for thermal plant cooling. Water for thermal plant cooling currently represents the most significant withdrawal demand in both the U.S. and Canadian regions of the Great Lakes. By the year 2015, significant increases in the United States are expected to raise consumptive uses for this purpose to dominant status as well. The majority of older thermal-electric generating plants in the United States, and most plants in Canada utilize once-through condenser cooling systems having significant water withdrawals and only minimal measured consumptive losses (although some additional consumption occurs due to increased evaporation of heated water after it is discharged to lakes and streams). In more recent years there has been increased use of "wet" cooling towers in the United States to dissipate waste heat via the evaporation of a portion of the water flowing through the tower. This process recycles the water, thus reducing withdrawals, but it is significantly more consumptive. As old plants are phased out and new plants are constructed, projected total water withdrawal rates for power generation in the United States will decrease, while consumptive use will increase substantially.

Manufacturing, the largest consumer of water in the region in 1980, will continue to be the largest consumer until the year 2015 when the levels of consumption for thermal plant cooling should catch up. Increases in manufacturing consumptive uses are primarily dependent on assumptions concerning technological changes in the various industries involved and the institution of closed recycling systems for cooling and process water in response to clean water laws, water availability and economic feasibility. In the United States, new industries are expected to meet the requirements of the U.S. Clean Water Act of 1972, which limits the discharge of polluted water to the environment. As is the case for the thermal-electric sector, this should result in reduced withdrawals but with substantial increases in consumptive uses. In contrast, recirculation and consumptive roles in Canada have been held constant over the forecast period with the result that consumptive uses should be low but withdrawals should be high.

Municipal water use, the third largest consumer of water in the region, was determined for the U.S. and Canadian sectors using roughly similar methods. Although there were differences in detail, demographic projections prepared by central statistical agencies underlie both.

In both countries, water for rural domestic use is relatively small and is largely drawn from wells, inland streams, reservoirs and other non-lake sources. Estimates were based on rural population forecasts and per capita rates of consumption.

Water is used for a variety of mining processes, including metals, non-metallic minerals and mineral fuels. The Great Lakes supply about 80% of mining water requirements in the region. Methodologies for developing both United States and Canadian figures were based on water use per production dollar in each mineral sector and projections were tied to each country's economic climate.

Rural stock water use refers to the withdrawal and consumption of water for the feeding and sanitation of livestock. Consumption, which is a comparatively minor portion of the total demand on the Great Lakes basin, includes animal drinking water and losses of cleaning and waste water.

Irrigation water, which is also a comparatively minor demand on the basin, is primarily drawn from non-lake sources. It includes the watering of crops, pastures, orchards, golf courses and public lands such as parks.

Table 5 indicates a possible rate of increase in each of the water use sectors by the years 2000 and 2035 on the basis of certain assumptions related to future water uses. Projections suggest that the MLP values of total consumption could increase to 24 000 mLd by the year 2000 and to 62 300 mLd by 2035, for a net change of 48 100 mLd from 1980. A measure of the uncertainty in forecasting economic scenarios is evident in the high and low projections of total consumption which are ±20% of the MLP value in the year 2000, and about ±40% of the MLP in 2035.

The action of increasing water withdrawals from the Great Lakes system is not as detrimental to water supply conditions as it may seem since a major part of the withdrawals are returned to the system for further use.

Water for cooling thermal generating plants such as this one currently represents the most significant withdrawal demand in both the U.S. and Canadian regions of the Great Lakes.

But the gradually increasing consumptive uses represent a different situation inasmuch as consumption contributes to a gradual decrease in net water supplies to the lakes which, in turn, lowers their levels and reduces their outflows, a consequence which is cumulatively greater downward through the chain of lakes. If forecasts to the year 2035 occur as projected, the increased consumption is expected to represent some 8.6% of the mean flow of the St. Lawrence River at the outlet of Lake Ontario, the most downstream lake. This level of consumption undoubtedly will limit the ability of the current operational plan to regulate the levels of and outflows from Lake Ontario. This has prompted authorities to recommend that consumptive uses continue to be monitored, and their impacts, along with various control strategies, be studied, so that appropriate public policies can be developed to minimize long-term adverse effects.

In the spring of 1979, the prairies and parts of Ontario and New Brunswick were scenes of swollen rivers, flooded fields and communities isolated by floodwaters. In contrast, 1980 produced the worst agricultural drought since 1961, resulting in parched farmlands over much of the Prairie Provinces. The problem has been one of extremes for the prairies.

The sharp contrast between 1979 and 1980 is not normal, for one of the characteristics of climate, whose mechanisms are still far from being clearly understood, is that wet years tend to follow wet years and dry years tend to follow dry years. This is the so-called persistency characteristics of climate. Examples are the drought years of the 1930s and the wet years of the 1940s and 1950s. Since 1965, the prairies have experienced a long wet spell broken only by the isolated dry years of 1973, 1976 and 1980.

The federal government and most of the provincial governments have undertaken cooperative programs of floodplain mapping and land use regulation to complement the system of flood protection works. Other initiatives being used or considered include floodplain management, land-use change, floodproofing, flood warning systems, equitable systems of flood insurance, and the collection and dissemination of information on flood damage, flood hazards and floodplain land, and improving design for flood protection works.

The economic and social impacts of droughts are so interwoven with the regional and national economics that their intricacies have become too complex for analysis without a great deal of research. For example, the drought of 1980 cost millions of dollars in lost sales to farmers on the Canadian prairies. Over the long term, this could grow to billions of dollars as its impact ripples through the Canadian economy.

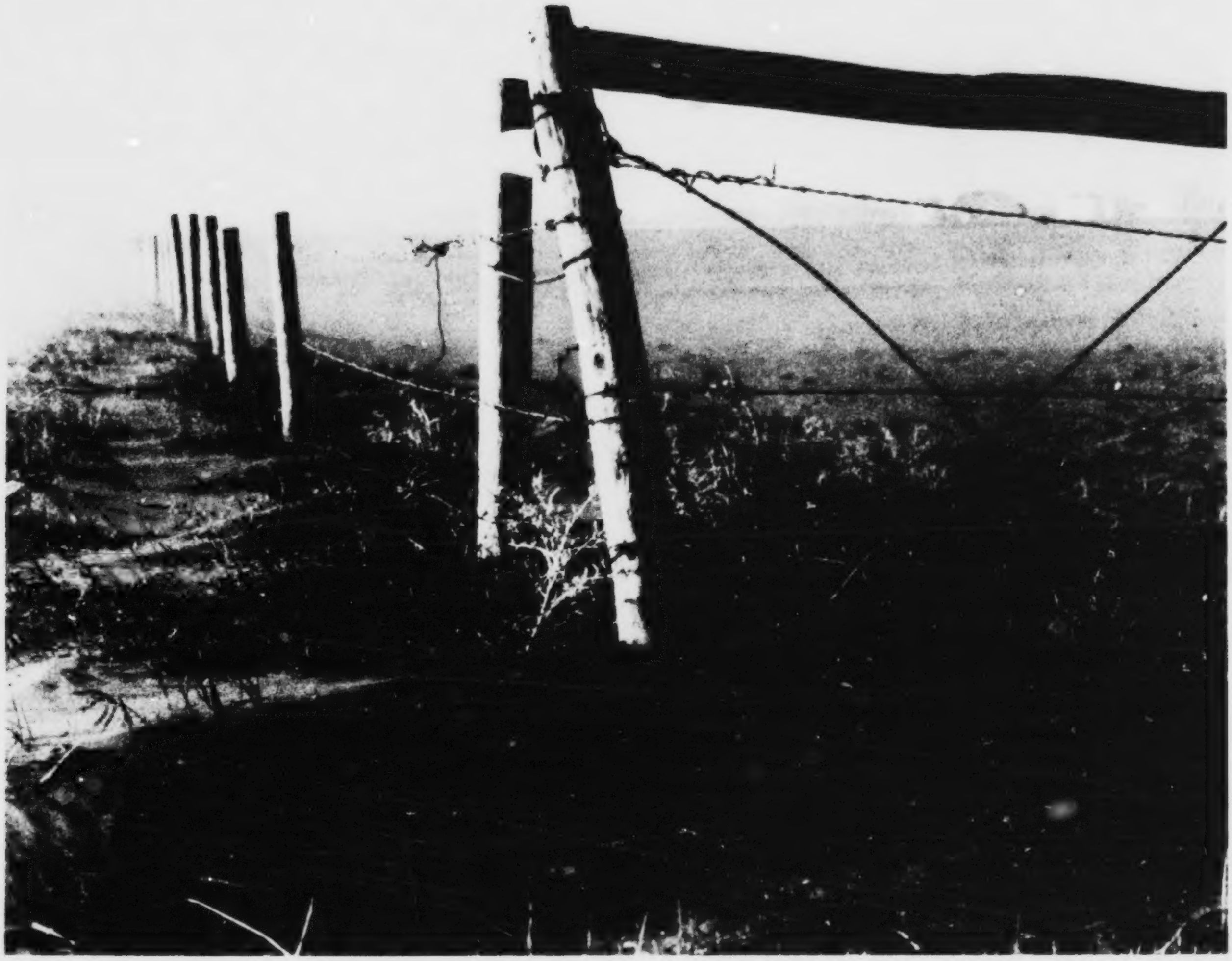
Many areas across Canada experience an over-abundance of water during part of the year, most often in springtime.

What would be the consequences of a long-term drought of several years or a widespread drought extending over many more provinces as well as other parts of North America? Currently, strategies for combatting drought include the development of more reservoir storage, interbasin transfer of water, more exploitation of ground water resources, and drought insurance. These may not be enough. More recognition must be given to indirect strategies such as increasing the price of water to discourage wasteful use, developing drought resistant plant strains, returning gradually to dry farming, increasing water yields through forest management, and increasing the availability of clean water through pollution abatement.

Floods and droughts cannot be tackled in isolation. Measures for their alleviation must be integrated into a systematic comprehensive long-term program that should take into account the conflicts between water uses and water users, and the social and economic impacts of various alternatives. Important among program objectives, in addition to flood damage reduction and protection of water supply, are the protection of floodways and floodplains from incompatible development; the abatement of water pollution; the preservation of land for parks and recreation; and the preservation of prime agricultural land, woodlands, wetlands and wildlife habitats. In general, programs must ensure wide and judicious use of the limited land and water resources of a region.

Depending upon their intensities and durations, the effects of flood and drought damage can range from minor inconveniences to widespread destruction, including loss of life. The two sections that follow highlight these effects.

The Prairie Provinces periodically experience prolonged dry spells as a normal characteristics of their climate.



Flooding and Its Impacts

Many areas across Canada experience an over-abundance of water during part of the year, most often in springtime. In moderation, this can be beneficial, but, when supplies exceed natural and man-made drainage capacities, flooding results. Flooding and flood damages have been a persistent problem in Canada. Because practically every major city in Canada has grown up along the bank of a river or lake, it is not surprising that as many as 200 communities from British Columbia to Newfoundland are subject to potential flood problems each year.

When flooding occurs its impact will vary greatly with its magnitude and location. A large flood may occur in an unsettled area, as often happens in northern rivers. A flood of this nature will have little effect on man. On the other hand, floods of smaller magnitude can create a disaster in areas where there is extensive settlement as is frequently the case in many of Canada's urban areas. Needless to say, large flood events in these areas are often catastrophic.

The usual way of assessing the impact of flooding is to examine resulting damages. Annual damages in Canada vary greatly. In some years, little damage results while, in others, such as in 1974, 1976 and 1979, damage can be extensive. In 1974, floods in six provinces and the Yukon Territory caused damages estimated at $70 million. In 1976, flood damages in the Montreal Region alone were approximately $30 million. In 1979, flood damage was widespread across Canada with residents along the Red River experiencing one of the largest floods on record.

There is no estimate available of the total costs of flooding over the years and even estimates of property damage are sketchy, being derived only for those floods of a major nature. Rough estimates of property damage in Canada from 1948 to 1973 range in excess of $100 million, ignoring inflation. There are many further unaccounted indirect damages that should be added to these dollar damage figures. Personal hardship, disruption to business, social disruptions, loss of productivity and lost economic opportunity are examples of indirect damages. These are further amplified as their effects are transmitted through the local economies. Regardless of how flood damages in Canada are calculated, they have been expensive and a consistently recurring problem.

Another way in which the impact of flooding can be regarded is to consider the amount of disruption that flooding causes. As floodwaters rise, there is an immediate effect on those in the flooded area. Local residents often have to be evacuated, sheltered and cared for, and initial flood fighting activities such as sandbagging, moving property, building temporary dykes, organizing alternate modes of transportation, and providing food, water and services must be instituted. A national system is in place, coordinated through Emergency Planning Canada, which preplans for floods and other natural diasasters.

When a large flood strikes, vast numbers of men and enormous quantities of equipment may be required for flood fighting. Personnel and equipment of the Canadian Armed Forces may be utilized for flood fighting when requested by the provincial government concerned. In the case of the 1979 Red River flood, the Armed Forces employed 700 personnel to help evacuate and relocate 7 000 residents, 11 000 head of livestock, 140 000 poultry and 2.7 million bushels of grain. Evacuated towns had to be patrolled and ring dykes constructed. Seven million sand bags had to be airlifted in. This type of scenario has repeated itself many times through the years in various areas in Canada.

In the post-flood period, assistance is offered to those persons who suffered damages. Provincial governments provide disaster assistance programs and, in some cases, municipalities or associations may arrange their own funds. Upon request the federal government will assist the provinces with flood damages which exceed $1 per capita. The formula for these payments is as follows:

Provincial Expenditures Eligible for Cost Sharing	**Federal Share**
First $1 per capita	0%
Second and third dollars per capita	50%
Fourth and fifth dollars per capita	75%
Remainder	90%

Not all damages are eligible for cost-sharing. Summer cottages, antiques, commercial establishments and crops, for example, are excluded. Disaster assistance is useful for offsetting the immediate impacts of flooding, but it does not offer a solution to the problem.

Another traditional means of dealing with the impacts of flooding has been the building of structural works. In early years, many of these schemes were undertaken by private individuals or small industry. A detailed look at flooding in early Canada would show many examples of failure of these works. In the early part of the 20th Century large scale water-projects were constructed to generate hydroelectric energy. Often, benefits for flood control also were realized. More recent water management schemes have been designed using the comprehensive river basin approach which resulted in further flood control benefits in many areas. Even in this case, however, flood control has to compete with a myriad of other considerations such as water quantity and quality, hydro generation and recreation. Trade-offs and loss of effectiveness in solving flood problems often result.

In some cases structural works have been implemented for the sole purpose of flood control with effective results. For example, the Red River Floodway, which is like an enormous by-pass valve that diverts excess flows from the Red River around Winnipeg, was built in the early 1960s at a cost of $65 million. Not only has it paid for itself but it is estimated that damages in the amount of $1 billion (1980 dollars) have been avoided since the floodway was installed. It is estimated to have prevented $284 million damage in 1979 alone.

Nevertheless, structural measures have their drawbacks. They are costly to build and maintain, they do not protect against all floods and there are often adverse environmental impacts. Of greater importance is the fact that once they have been built, structural measures often engender a false sense of security and encourage additional investment in areas subject to flooding. People often feel protected and intensify their use of land behind a dyke. When a flood of greater magnitude than the design flood of the structure occurs, or the structure itself fails, the total damage bill will be higher than before the structure was erected. This causes more lobbying for improved structures and a vicious circle begins. This situation can be further aggravated by interest groups lobbying for structures to protect undeveloped land so that it can be developed in safety to increase the municipal tax base.

The Flood Damage Reduction Program

Since 1975, the federal government, in cooperation with provincial governments across Canada, has been implementing the Flood Damage Reduction Program, which is designed to deal with the causes of flooding rather than its effects. This program is based on the concept that it is more sensible to limit the nature and flow of new investments on the flood plain, supporting compatible development in fringe areas, but discouraging all development from the most vulnerable locations. Over the long run, this approach should promote wise use of flood plain lands and reduce flood damages.

The policies of the Flood Damage Reduction Program are formalized by federal-provincial agreements. A General Agreement having a duration of at least 10 years, outlines the basic approach and is usually the first agreement that is signed when a province joins. Under the General Agreement, both governments agree to conduct a flood risk mapping program whereby lands subject to flooding would be clearly defined and designated; they also agree to abide by a number of policies restricting government undertakings and programs in designated flood risk areas. For example, they will neither build nor assist others to build flood vulnerable structures in such areas. This would include restriction of Canada Mortgage and Housing Corporation (CMHC) mortgages and Department of Regional Economic Expansion (DREE) incentives. Also, disaster assistance programs will apply only to structures built before the flood risk areas were designated and, under certain circumstances, to new structures which are flood proofed. As well, the General Agreement encourages zoning on the basis of flood risk. Where development has taken place in a flood risk area prior to designation, other means of reducing the flood hazard may be considered. Provision is made in the General Agreements for subsequent agreements to deal with these existing developments. Various options that could be considered include acquisition of property or easements, flood proofing, land use planning, flood forecasting and warning, and structural controls.

A Steering Committee, composed of two federal and two provincial members, is appointed to administer the General Agreement in each province. It is the duty of this Committee, which reports to the respective Ministers, to coordinate the ongoing program, to propose subsidiary agreements and projects necessary to carry out the program and to provide advice to the Ministers with respect to the lands to be designated.

Accompanying the General Agreement is the Mapping Agreement, which lists the flood prone areas to be mapped. The Mapping Agreement has a life of five years, which can be extended by mutual consent. Hydrotechnical and cartographic specifications for mapping form part of this agreement and a Technical Committee is usually established to ensure that the maps produced conform to these specifications. The Mapping Agreement also calls for a public information program to be carried out to inform the public about the purpose and implications of the Flood Damage Reduction Program and to make them aware of the availability of flood risk maps. It is on the basis of these maps that the Steering Committee will recommend designation of the flood risk areas to which policies outlined in the General Agreement will apply. The designated portion will correspond to the area that would be inundated by the highest flood expected to occur over a hundred-year period or longer. In some cases, a two-zone concept is applied, delineating both an inner, or highly active zone, in which flood waters occur most often, flow fastest and are most destructive; and fringe zones, in which flooding is not as destructive. In the two-zone concept, development in the inner zone is discouraged while some floodproofed development may be supported in fringe zones.

A Studies Agreement is one of several which could follow the basic General and Mapping Agreements. Extending for five years, it provides for studies to be carried out to determine the best measures to reduce flood damages to existing development in designated flood risk areas. The recommendations arising from such studies may be implemented through subsidiary agreements as provided for in the General Agreement.

The cost of the mapping and studies portion of the program is shared equally between the federal and provincial governments taking part. Subsidiary agreements may not necessarily be financed in this way since local governments may be required to contribute.

The Flood Damage Reduction Program was inaugurated in 1975 by the federal Minister of the Environment. In March 1976, New Brunswick became the first province to sign Flood Damage Reduction Agreements, and since then, six other provinces and the Northwest Territories have joined. Current status of the program and details on funding and areas affected are summarized in Table 6. Progress in the designation of areas or communities subject to flood risks is shown in Table 7.

Two provinces, New Brunswick in 1977, and Manitoba in 1981, have opted to enter into federal-provincial agreements to provide flood forecasting systems. The system for the Saint John River in New Brunswick has been implemented successfully for several years while implementation of the agreement with Manitoba is just getting under way. The latter agreement will provide a flood forecasting capability for the Red, Assiniboine and Souris Rivers, with a pilot project on the Boyne River.

There also have been several special federal-provincial agreements. In 1977, an agreement to provide structural works and land acquisition for the Marsh Creek area was signed with New Brunswick. The structural works commitment under this agreement has been completed but land expropriation is still under way. In 1976, the first agreement with Quebec was signed to provide structural works for the Montreal region. So far, dyking has been completed in several Montreal area communities and works are being considered for a structure to regulate flood flows on the Mille Iles River. Studies of storage capabilities in the Ottawa River watershed also are under way to determine among other things the feasibility of better controlling flood waters during the freshet period.

Negotiations are continuing with the governments of British Columbia, Alberta and the Yukon to obtain their participation in the program. Described later in association with shared-cost programs under the Canada Water Act is the Fraser River Flood Control Agreement and Construction program in British Columbia which predates the Flood Damage Reduction Program and currently is the largest single flood prevention program in Canada.

	Duration (years)	Total Cost* (dollars)	Expiry Date
Newfoundland			
General Agreement	10	—	1991
Flood Risk Mapping Agreement	2	350 000	1983
New Brunswick			
Amending Agreement	—	—	—
General Agreement	15	—	1991
Flood Risk Mapping Agreement	10	2 000 000	1986
Studies Agreement	10	200 000	1986
Flood Forecasting Agreement – Saint John River basin	10	1 400 000	1987
Flood Damage Reduction – Marsh Creek	4.5	2 010 000(a)	1984
Petitcodiac Sea Dykes Agreement	0.25	160 000	1979
Nova Scotia			
General Agreement	10	—	1988
Flood Risk Mapping Agreement	5	600 000	1983
Studies Agreement	5	300 000	1983
Quebec			
Combined General and Flood Risk Mapping Agreement	10	5 000 000	1986
	(mapping 6)		1982
Dykes and Flow Regulation Works – Montreal Region	4.8	11 556 000(b)	1981
Studies and Implementation of Dykes and Flow Regulation Works – Montreal Region	2	4 500 000(b)	1983
Ontario			
All Inclusive Flood Damage Reduction Agreement	10	1 200 000	1986
	(mapping 5)	6 000 000	1983
Manitoba			
Amending Agreement	—	—	—
General Agreement	14	—	1990
Flood Risk Mapping Agreement	8	2 190 000	1984
Studies Agreement	9	310 000	1985
Flood Forecasting	5	600 000	1986
Saskatchewan			
General Agreement	10	—	1987
Flood Hazard Mapping and Studies Agreement	(mapping 5)	1 300 000	1982
	studies	480 000	
Northwest Territories			
Memorandum of Understanding	2	225 000(c)	1978
Memorandum of Understanding	10	400 000(c)	1989
General Agreement	(mapping 5)		1984
	10	—	1989

* These costs are to be shared equally by the federal and provincial governments except for
(a) 33-1/3% federal, 66-2/3% provincial/local
(b) 45% federal, 55% provincial/local
(c) costs shared equally by Environment Canada and the Department of Indian and Northern Affairs

** This agreement applies to flood vulnerable sections of streams and rivers under the jurisdiction of 38 Conservation Authorities, 10 rivers, 4 lake shorelines.

Table 7

Designations Under the Flood Damage Reduction Program

March 31, 1982

Designated Area	Community	Body of Water	Date
New Brunswick			
Fredericton	Fredericton	Saint John River	February 1980
Perth/Andover	Perth/Andover	Saint John River	February 1980
Oromocto to Lower Jemseg	Oromocto/Lower Jemseg	Saint John River	March 1981
Lower Fredericton Lincoln	Fredericton/ Lincoln	Saint John River	February 1982
Quebec			
Montreal Region		Lac Saint-Louis	May 1978
	Baie d'Urfé		
	Beaconsfield		
	Beauharnois		
	Châteauguay		
	Ile-Perrot		
	Lery		
	Maple-Grove		
	Melocheville		
	Notre-Dame-de-l'Ile Perrot		
	Pincourt		
	Pointe-Claire		
	Pointe-des-Cascades		
	Pointe-du-Moulin		
	Sainte-Anne-de-Bellevue		
	Senneville		
		Lac des Deux Montagnes	May 1978
	Deux-Montagnes		
	Dorion		
	Hudson		
	Ile-Cadieux		
	Oka		
	Pointe-Calumet		
	Sainte-Marthe-sur-le-Lac		
	Saint-Joseph-du-Lac		
	Saint-Raphaël-de-l'Ile Bizard		
	Terrasse-Vaudreuil		
	Vaudreuil		
	Vaudreuil-sur-le- lac		
		Rivière des Prairies	May 1978
	Laval		
	Montréal		
	Montréal-Nord		
	Pierrefonds		
	Roxboro		
	Sainte- Geneviève-de-Pierrefonds		
		Rivière des Mille Iles	May 1978
	Boisbriand		
	Bois-des-Filion		
	Charlemagne		
	Lachenaie		
	Laval		
	Lorraine		
	Rosemère		
	Sainte-Thérèse		
	Saint-Eustache		
	Saint-Louis-de-Terrebonne		
	Terrebonne		
Gatineau/Ottawa Rivers		Ottawa River	October 1979
	Aylmer		
	Buckingham		
	Gatineau		
	Hull		
	Pontiac		
		Gatineau River	October 1979
	Bouchette		
	Cameron		
	Deléage		
	Denholm		
	Egan-Sud		
	Gatineau		
	Gracefield		
	Grand-Remous		
	Hull – Ouest		
	La Pêche		
	Low		
	Maniwaki		
	Northfield		
	Sainte-Thérèse-de-Gatineau		
	Wright		

Designated Area	Community	Body of Water	Date
Chaudière Basin		Chaudière	May 1979
	Aubert-Gallion		
	Beauceville		
	L'Enfant-Jésus		
	Notre-Dame-des-Pins		
	Sainte-Marie		
	Saint-François-de-Beauce		
	Saint-François-Ouest		
	Sainte-Georges-Est		
	Sainte-Georges-Ouest		
	Saint-Isidore		
	Saint-Joseph-de-Beauce (p)		
	Saint-Joseph-de-Beauce (v)		
	Saint-Lambert-de-Lauzon		
	Scott		
	Taschereau-Fortier		
	Vallée-Jonction		
du Gouffre		du Gouffre	April 1980
	Baie-Saint-Paul (p)		
	Baie-Saint-Paul (v)		
	Rivière-du-Gouffre		
	Saint-Urbain		
Upper Richelieu River	Chambly	Richelieu	April 1981
	Clarenceville		
	Henryville		
	Iberville		
	Lacolle		
	Notre-Dame-de-Bon-Secours		
	Notre-Dame-du-Mont-Carmel		
	Noyan		
	Philipsburg		
	Richelieu		
	Saint-Alexandre		
	Saint-Antoine-de-Padoue		
	Saint-Armand-Ouest		
	Saint-Athanase		
	Saint-Bernard-de-Lacolle		
	Saint-Jean		
	Saint-Luc		
	Saint-Paul-de-l'Ile-aux-Noix		
	Saint-Pierre-de-Veronne		
	Saint-Sébastien		
	Venise-en-Québec		
Lower Richelieu River		Richelieu	November 1981
	Beloeil		
	Carignan		
	Chambly		
	McMasterville		
	Mont-Saint-Hilaire		
	Otterburn-Park		
	Richelieu		
	Saint-Antoine-sur-Richelieu		
	Saint-Basile-le-Grand		
	Saint-Charles-sur-Richelieu		
	Saint-Denis (v)		
	Saint-Denis (p)		
	Saint-Pierre-de-Sorel		
	Sainte-Victoire-de-Sorel		
	Saint-Joseph-de-Sorel		
	Saint-Marc		
	Saint-Mathias		
	Saint-Ours (p)		
	Saint-Ours (v)		
	Saint-Roch-de-Richelieu		
	Sorel		
	Tracy		
Manitoba			
Melita*	Melita	Souris River	December 1979
Wawanesa*	Wawanesa	Souris River	December 1979
Winnipeg*	Winnipeg	Red, Assiniboine	February 1979
Souris	Souris	Souris River	October 1980
Elie	Elie	Rivière Sale	November 1980
Brandon	Brandon	Assiniboine	March 1982
Saskatchewan			
Estevan*	Estevan	Souris River	August 1980
Oxbow*	Oxbow	Souris River	August 1980
Roche Percee*	Roche Percee	Souris River	August 1980
Moose Jaw	Moose Jaw	Moose Jaw River	October 1981

p – parish
v – village

* interim designation

Drought and Its Impacts

The Prairie Provinces periodically experience prolonged dry spells as a normal characteristic of their climate. The economy and society are in general adjusted to withstand or compensate for the inconveniences and losses of income associated with these occurrences, knowing that problems will be alleviated in a few months. Occasionally, however, serious dislocations to agriculture and other sensitive water resource activities are the result of unusually severe and prolonged dry periods. These fall into the generally conceived definition of drought – a condition requiring evidence of damage to the regional economy and social structure.

There are two main categories of drought – an agricultural drought and a water drought. The agricultural drought is reflected in abnormally low soil moisture over an area or region; a water drought occurs when water supply, as measured by streamflow, lake levels and ground water levels, is abnormally low.

The number of people affected by a drought depends upon the type of drought, its location, duration and severity. A brief soil moisture drought would primarily affect the farmers; the effects of a prolonged soil moisture drought would go beyond the farmers to individuals such as farm implement dealers, fertilizer and pesticide salesmen and in general the shopkeepers of the small farm towns who depend on the farmers for their economic livelihood. If the drought is very severe and prolonged, individuals in other parts of the province, country or world-wide could be affected by the weakened economic situation or reduction in food available.

One of the main characteristics of droughts is the extended length of time involved in their development, propagation and termination. There are no sharply defined onset nor termination points. It is for this reason that drought has been termed a creeping phenomenon.

The 1979-80 edition of the Canada Water Year Book dealt with drought alleviation in terms of the research undertaken to alleviate the effects of drought. This Year Book concentrates on drought's impacts, and discusses some of the social, economic and environmental effects resulting from drought.

Regions Susceptible to Droughts

Regions which are likely to experience frequent drought recurrences are the ones classed as semi-arid, that is, those that normally receive only 25 to 50 cm of precipitation each year. Medicine Hat, Alberta, is in a typical semi-arid region since it averages only 35 cm of precipitation annually. In such regions, the margin between supply and demand is continually small. Often, the annual precipitation is produced largely from a few major storms or within a short time span within the year. If atmospheric conditions are such that the number of storms is reduced or the normal period of precipitation shortened, this could represent a significant decrease in total precipitation. For the prairies, snow cover and spring snowmelt (or the lack of these) are also important factors.

In contrast, in humid or semi-humid regions, one or two less storms or a two to four week reduction in the maximum precipitation period will not have as great an effect on the total precipitation.

It is mainly when water demand begins to approach the diminishing supply level that this situation becomes of economic and social concern.

Causes of Droughts

Despite the fact that droughts have been occurring throughout the world for hundreds of years, they are still a poorly understood event. It appears that the major factor in the onset and perpetuation of droughts is the circulation of air in the upper atmosphere. For example, in September 1976, the interior of western Canada entered a drought period. The atmospheric circulation generated conditions known as a "blocking pattern", a high pressure ridge anchored over western Canada which steered rain-carrying storms from their easterly path. This pattern is not unusual; what was unusual was the fact that the pattern persisted for 8 months and was broken only when the atmospheric circulation changed abruptly in May 1977. Storms broke through and brought rain to most of the plains and northwestern Ontario. The May rains were copious, near record in many places, and presented a remarkable turnaround.

Trying to understand why droughts happen is just one segment of the much larger problem of trying to understand the forces that control the world's weather and climate. With the advent of sophisticated satellites which have facilitated the collection of world wide atmospheric data and the increasing use of computers which have enabled the processing, verification, compilation and storage of large volumes of data as well as the development of complicated models, great advances are being made in developing an understanding of the interrelationships and driving forces which control weather. However, such knowledge is still limited in extent.

Various approaches have been tried in an effort to develop some means of estimating the time of occurrence of the next drought.

The most popular method is based on the postulation that climatic cycles exist. Historical data have been collected and analysed to determine if there is any regular periodicity associated with drought occurrence.

To date, knowledge of the drought phenomenon has not progressed to the extent where prediction of future droughts is feasible. The best forecasting tools available offer results which are uncertain since they are only able to provide an estimate of the likelihood of a drought event occurring during some lengthy time period. But what is known with certainty is that for some areas of the world, Canada's prairies included, drought is an integral part of the climatic regime. In such areas, the future occurrence of drought is virtually guaranteed.

Historical Droughts

Although drought events in recent times stand out as being extreme events, examination of historic climates reveals that historical droughts have been much more severe.

Determining the history of earth's climate back beyond recorded meteorological records is a painstaking job. The tools used in this task include the analyses of tree rings, lake sediments, glacier ice cores, skeletal remains of animals, as well as the examination of chronicles, sagas, songs and explorer's journals. The location of early settlements, the means of livelihood in such settlements, examination of historic documents such as the record of wine harvest and numerous other factors have supplied the clues to prevailing climatic conditions.

Drought in the 1930s: It took more than a diminished amount of rainfall to cause the agricultural problems experienced on the prairies in the 1930s. And it took more than the return of normal levels of rainfall to alleviate the problems. One of the basic problems of the 1930s was the need to control soil drifting. This was achieved in part through the introduction and widespread use of a variety of agricultural practices. Strip farming, plowless fallowing, trash cover, and the development of new farm equipment were some of the innovations tried which would control soil drifting, and conserve as much soil moisture as possible. Also, crested wheat grass played an extremely important role in containing and reclaiming the developing desert. Experiments led to effective means of controlling grasshopper infestations, and rust tolerant species of wheat were developed. All of these contributions to the productivity of dry lands on this continent have brought world-wide recognition to Canada and have served to ease the burden of the farm family in subsequent years.

One of the serious consequences of the drought of the 1930s was the disruption to normal social life on the prairies. Between 1931 and 1941, almost 250 000 persons left the prairies. For example, the Royal Commission for the South Saskatchewan River estimated that 10 000 families moved from the farms of south Saskatchewan into northern parts of the province. Farm families from Saskatchewan also crossed into western Alberta and British Columbia. Some families from the Manitoba dust bowl moved onto Manitoba parkland, or to the cities. Hundreds of Alberta farm families were moved from the central region to better farm land elsewhere.

Because of the soil drifting problems during the 1930s, it was not uncommon for good topsoil to be drifted 1.2 to 1.5 m deep in farm yards. The blowing soil, particularly from abandoned lands, became an increasing problem. With no one trying to control the blowing soil, the wind would blow it with such force that it cut down and destroyed the crops that were growing on neighbouring fields. When the neighbour's farm was in ruin, that family would often pack up and move out, and the whole problem would be doubly compounded.

The amenities of life for the farmers were also undermined. The country roads which gave them access to town became impassable, with drifts reaching to the height of fence posts. With their livelihood virtually destroyed and devastation all around, many prairie families became discouraged.

While leaving the dust bowl was a necessity for many families, it was not a viable solution for all. However, the disruption to normal living patterns stood out as a major event in the 1930s and reflects the effect of the drought as well as other factors on the social and economic life of prairie communities.

Recent Droughts: The most recent drought events on the Canadian prairies occurred in 1976-77 and 1980.

The earlier event began in September 1976 and lasted eight months, ending with copious rains in May 1977. The later drought, reaching across western Canada into northwestern Ontario, began in June 1980; however, it ended in parts of Alberta first and the return to normal by August 1980 was a gradual one moving from west to east. In addition to differences in timing, these two drought events also differed in impact.

The earlier drought reduced the accumulated snowpack in the mountainous areas in the headwaters of the South Saskatchewan River; accumulated runoff for the period April to July 1977 ranged from 30-65% of normal. The eight dry months drove streams, lakes, reservoirs and wells to dangerously low levels and, even in areas where summer rains were above average, the recovery was limited. Although of relatively short duration, this drought caused runoff to fall to the range of, and sometimes below, previous low flows (Table 8).

The 1980 drought event did not have as significant an impact on streamflows and water levels, but was felt more strongly by the agricultural community, especially the livestock industry when spring precipitation did not arrive to allow pastures to recover.

Drought (and Related) Impacts

When drought strikes, it permeates a region and impacts upon everything and everyone with which it comes into contact. Although some of these impacts will be reflected in physical conditions of the region, the social and economic elements will also be affected. For example, a number of localities affected by the droughts of both the 1930s and 1976-77 physically experienced more extreme conditions in the recent period than in any year in the 1930s. Nevertheless, better economic conditions in the 1970s and the shorter duration of the recent drought resulted in their having lesser impact than the drought of the 1930s. Some of the recent impacts are described in the following.

Municipal Water Supply: Today, the water supplies in most large cities in western Canada are free from interruption, even in times of low flows such as in 1977. Many cities are located on or near a major river which supplies good quality water from a reliable source. Others have experimented with ground water supplies or small streams but have opted for alternatives which, at the time, may have been more costly. For instance, the City of Winnipeg obtains its water supply via a 150-km aqueduct from the Lake of the Woods. This alternative has proved its worth to Winnipeggers on many occasions since its inception.

Small communities lack the resources to reach out to reliable water supplies. Consequently they must develop sources close by. In many cases, these become unreliable during an extended dry period. As a result, some prairie communities are served by canals such as the Saskatoon South East Water Supply System in Saskatchewan and the irrigation districts in southern Alberta.

During the 1976-77 drought in Alberta, seven communities required emergency pumping to augment their water supplies. Several other communities were in marginal positions. Within Saskatchewan, emergency augmentation was planned or implemented for 49 communities. No Manitoba communities experienced water supply shortages entirely due to the 1976-77 drought.

Wildlife: In their natural state, prairie sloughs and the surrounding plant communities are the most productive wetlands in North America. Up to 75% of the ducks in North America are produced on prairie wetlands. In an average year, Alberta, Sakatchewan, and Manitoba respectively support 7 900 000, 10 600 000 and 3 500 000 breeding ducks of all species. Many other wildlife species are also dependent on prairie wetland complexes.

Even in an average year, evaporation exceeds precipitation, so that by midsummer, many potholes have dried up. When a drought occurs, a large number of basins become dry.

Combined with the effect of the natural climatic conditions are man-made environmental changes which further serve to increase the impact of droughts on wildlife—and on waterfowl, in particular. The rising value of agricultural land, the wet years of 1969 through 1974, and the advent of heavy duty farm machinery have combined to stimulate a gigantic increase in wetland drainage projects on the prairies. In addition, the upland vegetation surrounding wetland basins has been burned and cleared in many areas. The net result has been a reduction in the number of breeding pairs in many regions and a decline in the reproductive success. For example, the reproductive success for Mallard hens has declined from 50-70% in the 1950s to less than 10% on many prairie areas today.

It is difficult to quantify the exact magnitude of the effect of droughts on wildlife, and waterfowl in particular, but it is known to be significant.

Prairie Fishery: A true economic measure of fishery values has not yet been successfully achieved. License fees are used by government to cover some of the costs of management and as statistical measures, but they rarely reflect what the resources would be worth in a competitive market. Nevertheless, the direct revenue from licence sales on the prairies approaches $2 000 000 ($800 000 non-resident), while commercial fish production values approach $9 000 000. The latter figure applies specifically to the prairie lakes, which are those most affected by prolonged drought conditions.

Sport fishing is an important recreational pursuit on the prairies. In fiscal year 1975-76, the number of angling licences issued totalled approximately 180 000 in Manitoba, 175 000 in Saskatchewan and 220 000 in Alberta. Besides representing a direct revenue to the respective provinces, the licences generate a twenty-fold increase in indirect monetary transactions, not taking into consideration purchase of boats, motors, or trailers.

The commercial fisheries in the region is also of significant value, both economically and socially.

Droughts may have short-term impacts on the prairie fishery which could be serious on a local basis. A drought can affect the fish population in one or more of the following ways: decrease water levels and thus endanger survival and inhibit spawning of some species; cause winterkill due to the shallow water bodies and streams freezing to the bottom or ice thickness causing deficient oxygen supplies; reduce spring runoff which inhibits spring spawning success of such species as walleye and pike; decrease water quality; increase competition for food and habitat; and restrict migration from one lake to the next.

Adjustment of water management regimes could offset some of the adverse effects on fisheries. On the whole, fisheries populations can withstand a temporary restriction in habitat or the loss of one season's reproduction, but longer-term impacts are more damaging.

Hydroelectric Generation: The significant reduction in streamflows in 1976-77 had an appreciable effect on hydroelectric generation across the prairies.

In Manitoba, the below normal 1977 spring freshet in the Saskatchewan and the Red River drainages, and severe reductions in the flow of the Winnipeg River, resulted in serious shortages of water for hydroelectric generation. By mid-June, 1977 storage releases from Lake Winnipeg were reduced sufficiently to severely affect hydroelectric generation at plants on the Nelson River. To counteract the shortfall in hydroelectric generation, Manitoba Hydro shifted a substantial load to thermal plants and brought in offpeak power from other systems. The Nelson River plants were shut down during the night to build up storage for daytime operations and the diversion from the Churchill River to the Nelson River was operated at the highest possible rate. Estimates show that the increased use of thermal plants in Manitoba to October 1977 resulted in the consumption of 2 million tonnes of coal, compared to 200 000 tonnes in an average year.

In Saskatchewan, the principal storage reservoir is Lake Diefenbaker. Because of the reduced level of the 1977 spring runoff on the South Saskatchewan River, Lake Diefenbaker remained below full supply level. In order to retain as much summer flow as possible, reservoir releases were cut to the minimum allowable in late April, with a consequent reduction in the number of units operating in the Coteau Creek Station at Gardiner Dam. In mid-July 1977, the Lake Diefenbaker level was 4.9 metres below normal, at approximately 40% of total usable storage. The increased cost of thermal generation to make up the shortfall in summer generation at the Coteau Creek and Squaw Rapids stations, as a conseqence of the low level of Lake Diefenbaker, was estimated at $7 million.

Within Alberta, approximately 10% of Alberta's electrical load is met by hydroelectric generation in the Bow and North Saskatchewan River Systems. Flows on the North Saskatchewan were approximately 80% of average in 1977 and power generation was maintained near normal. Because flows on the Bow River were much below normal in 1977, most power reservoirs failed to fill during the 1977 runoff. However, hydroelectric generation from the Bow River plants was maintained near normal with some load transferred to thermal generation.

From the foregoing, it is evident that the impact of drought on hydroelectric generation can vary across the prairies. The factors which determine the magnitude of the impact include the proportion of the total electric generating capacity of the province met by hydroelectric sites, the amount of natural and man-made storage which can be utilized at each generating site, and whether there are any competing uses along the same water source used for hydroelectric generation. In addition, the relative departure from the average streamflow will also significantly affect the extent of the drought impact on hydro.

Water Quantity and Quality: The quality of any water body is determined, in part, by the quality and quantity of the waters reaching it. The water in a water body can be sustained by inflow from snowmelt and rainfall, ground water discharges, from natural or man-made channels, or effluent discharges. The properties of water provided from these sources, each with its own distinctive characteristics, affect the quality of the receiving waters.

In the prairie environment, the quality of the various water sources differs greatly and drought conditions accentuate these differences. Snowmelt and rainfall are of relatively good quality and, in years when the streams contain a large proportion of water from these sources, water quality is relatively good. Furthermore, during years of ample precipitation, water managers can impound some of this relatively good quali-

[redacted]

Station Name	August 1977 M³/s (ac-ft)	Long-Term Mean August M³/s (ac-ft)	Long-Term Mean August Period	Previous Recorded Low Flow – August M³/s (ac-ft)	Previous Recorded Low Flow – August Year
Red Deer River at Red Deer	44.8 (97 300)	64.8 (141 000)	1912-1979	29.0 (63 000)	1936
Bow River at Calgary	89.9 (195 000)	133 (289 000)	1908-1979	83.9 (182 000)	1957 1979
Oldman River near Lethbridge	8.30 (18 000)	43.4 (94 000)	1912-1948, 1958-1979	5.96 (12 900)	1936
South Saskatchewan at Medicine Hat	75.6 (164 000)	167 (363 000)	1912-1979	47.0 (102 000)	1936
Assiniboine River at Headingley	15.6 (33 900)	36.5 (79 300)	1913-1979	3.50 (7 600)	1961
Saskatchewan River at The Pas	365 (793 000)	1050 (2 280 000)	1913-1979	388 (843 000)	1979
Winnipeg River at Slave Falls	217 (471 000)	860 (1 870 000)	1907-1979	346 (751 000)	1931

ty water for subsequent use.

During any dry periods, streamflow will often be sustained from ground water sources which, on the prairies, are frequently rich in dissolved salts and nutrients. During the summer of 1977 most prairie streams had the highest concentration of dissolved solids since measurement of concentration began in 1960. For example, the chloride levels in the Red River in 1979 were about ten times their normal summer level because a saline aquifer feeding the river was a major contributor to the flow of the river.

Lower streamflow and the reduced amount of clean water in streams during drought periods reduces the capacity of a stream to dilute effluent concentrations. In 1977, higher than normal levels of 2-4-D were noticed in both the North Saskatchewan River and the Red River. The sources of this herbicide were effluent discharges in Edmonton and Winnipeg respectively. Since there did not appear to be any change from previous years in the pattern of effluent discharges, the levels of the herbicide were attributed to the drought-induced lower flows in the river.

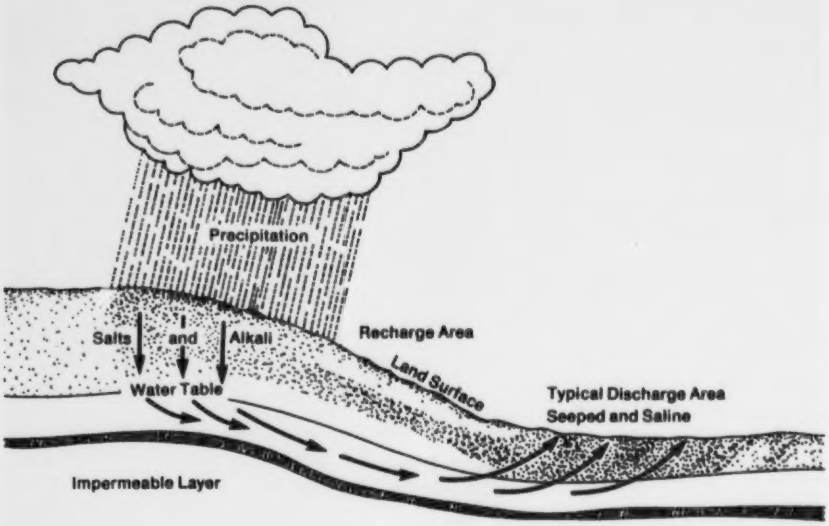
The foregoing discussion could apply to most parts of Canada during a period of dry weather but, the Prairie Provinces, with the lowest amount of runoff of any region of Canada, are especially affected. As a result, a large number of streams on the prairies are regulated to alter the temporal distribution of the prairie water. Large volumes of water are available during spring runoff to the point of bank overflow and flooding. By regulation, some of this water can be held back for later periods when water availability is less. Special redistribution, or diversion, is also practical, particularly in southern areas of Alberta and Saskatchewan. In this regard, the prairie experience is not typical of the rest of Canada since most diversions in Canada are implemented for hydroelectric power production; on the prairies, most diversions are undertaken to provide water for irrigation.

Farmland Productivity: The foregoing has described some of the impacts of drought on the prairie region of Canada, including the loss in farmland productivity. But there are other water-related factors contributing to losses in farmland productivity.

Before the prairie soils were developed for grain production, the soils, largely under native grass, were fertile and had high organic matter content. The depth of water percolation was limited because the native grasses used the moisture as soon as it became available. But subsequent agricultural development of the prairie grasslands has had serious effects on the fertility and salinity of the soil. Salinity refers to the presence of water soluble salts in amounts that adversely affect plant growth.

Tillage practices, particularly in the dryland farming area, have caused deeper water percolation and introduced the associated problems of increased soil salinity and decreased fertility (see Figure 1). These cultural practices have also resulted in increased wind and water erosion. Experience in similar arid lands which have been farmed for some time indicates that many of these problems are cumulative and the soil capability permanently impaired unless significant soil conservation measures are implemented.

Over the last 30 years, wind erosion and farm water supplies on the prairies have, for the most part, not been major problems because of adequate precipitation as well as the adoption of some remedial programs. Also, substantial increases in production have occurred because of improvements in machinery, crops, fertilizers,



herbicides, pesticides and management techniques. These increases have tended to mask the effects of the deterioration of the soils.

Recently, it has been highlighted in the media that the cultivated soils of the prairies are deteriorating significantly because of a combination of changed soil moisture regime, wind and water erosion, loss of fertility and increasing salinity. It has been estimated that the productivity of native prairie soils has decreased by some 30% since settlement began. About 10% of the cultivated area is now affected by salinity and the affected area is increasing by about one percent per year. In Saskatchewan alone, the area of saline soils within the improved or cultivated acreage was estimated at 1 600 000 ha in 1976, a four-fold increase over the 400 000 ha estimated in the early 1950s.

Salinity and loss of organic matter seriously reduce the soil's capacity to store water for the use of plants. The agricultural area of the prairies is traditionally short of adequate precipitation, and this further reduction in water availability increases the region's sensitivity to drought. Measures to ensure the economic security of agriculture on the prairies must, therefore, be based on maintaining the long-term quality of the soil resource and its ability to ensure maximum use of whatever water is available.

Unique prairie soil problems will require unique solutions. In addition to soil salinity, soil erosion by wind and water continues to destroy valuable fertile topsoil. Also, soil acidity is a growing problem with approximately 12.8 million acres of agricultural land now affected. Currently, growing pressures on the limited water supply and a deteriorating soil resource will require improved soil and water conservation techniques if major economic development opportunities are not to be lost. Solutions may lie in improved cultural practices – water and snow management, irrigation and drainage.

Forest Fires: The 1980 forest fire season in Canada was the worst on record with more fires started and more area burned than any earlier year. Fire management costs, totalling some $140 million, also were record high, almost double the previous high of 1976. Many persons were evacuated when forest fires advanced towards their communities, but only one life was lost through causes attributable to forest fires. The fires had only a slight effect on total forest growth stock and on allowable cut.

The 1980 forest fire season in Canada was the worst on record with more fires started and more area burned than in any earlier year.

Fire in the Canadian boreal forest is a naturally recurring phenomenon to which the vegetation and wildlife are well adapted. Jackpine, for example, produces serotinous cones that open and scatter seed after a forest fire. A post-fire increase in browse and seedbearing plants often leads to an increase in the number of moose, small mammals and birds. Ecologically, fire need not be an unmitigated disaster.

Over the 60 years of fire records in Canada the annual area burned appears to have declined steadily until the late 1970s. Many foresters have attributed the reduction in area burned between 1920 and 1970 principally to the introduction of intensive fire control procedures. Data from the 1970s, however, show a sharp rise in annual area burned and implicate weather as an important continuing influence.

The statistics on fire occurrence are particularly interesting when compared to those on area burned. In the earlier period, the number of fires remained nearly constant whereas the area burned steadily declined. After 1975 the area burned increased rapidly. Discounting reservations on data accuracy, one could conclude that the weather between 1950 and 1972 was not conducive to the development of large forest fires, whereas the late 1970s represent a return to a more normal variation in climate. Such a conclusion is not unreasonable when it is considered that during the post-war years, and until the late 1970s, rainfall had been plentiful on the Canadian prairies.

Weather plays a unique role in forest fire occurrence, while accompanying winds are an important factor in fire spread. Drought, defined as a soil moisture deficit, may have little bearing upon fire severity. If the litter layer and upper layers of duff are dry, then a fire may range across the landscape despite fully moisture-charged soil below. The best rains for agriculture are slow soakers of considerable depth that recharge the soil. The best rains for fire prevention are frequent showers that never permit the litter and duff to dry completely. A severe long-term drought, however, will affect both agricultural production and forest fire incidence adversely.

A study of the data for 1980 reveals that the severe drought in Ontario and Manitoba was restricted largely to areas of intense fire protection; had this not been the case, the forest fire season in these provinces probably would have been worse. The same applies to Saskatchewan where fire size increased seven-fold within the area of intensive protection but only four-fold in more northerly areas with less protection.

The economic impact of a forest fire is exceedingly difficult to assess in any meaningful way at present, primarily because of deficiencies in the data base. For the forest itself, fire may renew decadent forest and in other ways provide a net ecological gain.

From data available, it is difficult to prove that the 1980 fire season did any serious damage to the industry. Table 9 shows the apparent effect of the 1980 fire season on the annual allowable cut in Alberta and northwestern Ontario. From this broad regional viewpoint, no significant impact on timber supplies in Alberta and northwestern Ontario relative to levels of use is apparent. Even the huge timber losses of 1980 appear to have had only a marginal effect on the total growing stock and a slight effect on the annual allowable cut in Alberta and northwestern Ontario. It appears that timber surplus in unburned areas may be substituted for losses. A severe fire season in areas where the utilization is close to the annual allowable cut, such as in British Columbia or southern Ontario, would affect annual allowable cut to a much greater extent. In particular, large operators may find alternative sources of supply within their management unit. Some individual management units, particularly those of small operators, may have been more seriously affected.

In conclusion, the 1980 fire year appears to have had a negligible effect on the forest industry in regions where the harvest was significantly less than the allowable cut and where the forest was ecologically adapted to fire. But, if a longer series of dry years recurs, similar to those in the 1930s, it would not only impact on governments and fire management personnel, but could conceivably have a serious effect on the forestry industry as well.

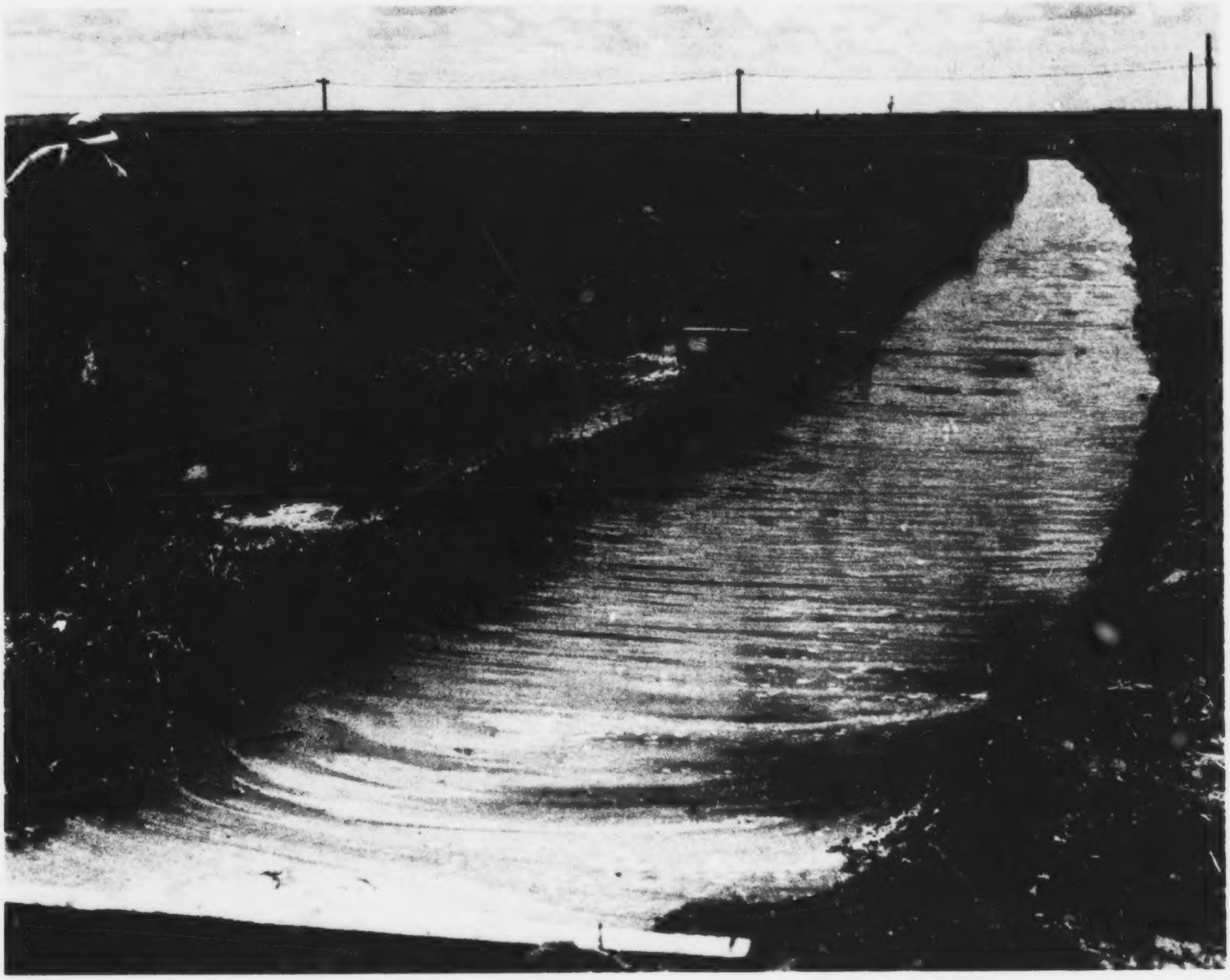
Province	Forest Inventory	Annual Allowable Cut	Average Annual Harvest	Timber Burned
Before 1980 Fire Season				
Alberta	1 696 425	24 916	6 784	—
Northwestern Ontario	1 150 185	13 914	6 616	—
After 1980 Fire Season				
Alberta	1 676 054	24 649	6 784	20 371
Northwestern Ontario	1 126 365	13 400	6 616	33 800

Source: The 1980 Forest Fire Season, J.B. Harrington

Western Canada is currently the nation's fastest growing region. In part, this rapid growth is statistical in nature, constituting movement from a small base. But, the growth is also real and significant, based upon the region's large and varied resource base. In the national context, this growth is tremendously important in at least two ways. In terms of economics, expenditures of this type have multiplier effects, particularly in central Canada. For example, each dollar spent in the hydrocarbon extraction process has over 40 cents worth of impact in Ontario, greater even than the impact on the prairie region itself. In terms of economic geography, western growth will likely result in the re-alignment and weakening of traditional heartland-hinterland relationships in Canada, relationships which have been largely responsible for the economic disparities in this country since Confederation.

In 1976, the population of the three Prairie Provinces stood at 3.8 million persons. In 1975, Statistics Canada's highest growth rate for this region was estimated to be about 1.7% annually, suggesting a total regional population of 5.8 million by the year 2001. Since then, the rates have been revised upward and, in 1981, the upper limit of the rate was 3%, giving a total population of just under 8 million in 2001. This estimate may be too high because of lack of large markets and high transportation costs, which may discourage growth and capital formation. The final figure will likely

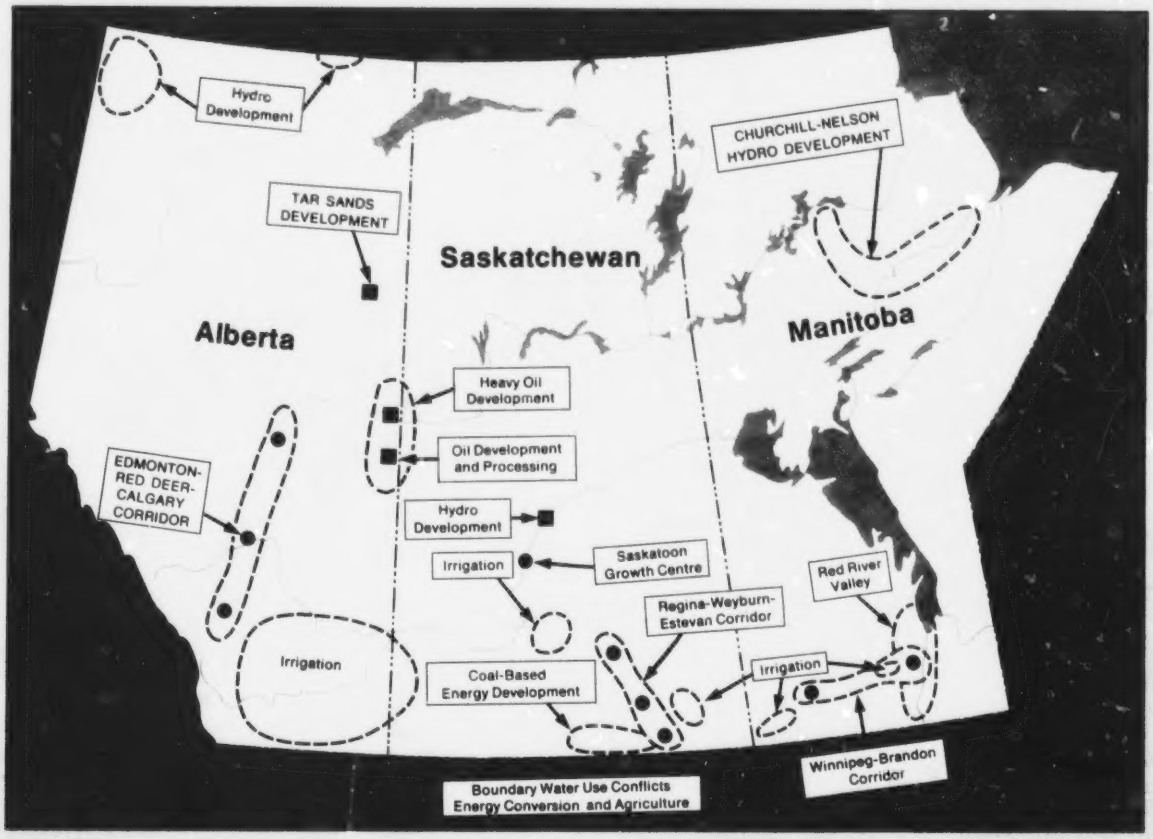
Agricultural expansion is likely in the South Saskatchewan basin based upon growth in irrigation.



fall between 6.5 and 7 million persons. This population will be increasingly urban, and occupied principally in the tertiary or service sector of the economy.

While this growth will initiate a corresponding rise in water use and demand if current resource use policies continue, one must look at some of the massive primary and secondary sector projects envisaged for the largest impacts on water use. Figure 2 illustrates some projects from today's vantage point. Most of these developments would be based upon the West's massive resource potential.

In Alberta, major coal developments are forecast for the eastern slopes of the Rock-


Hydro Development
CHURCHILL-NELSON HYDRO DEVELOPMENT
TAR SANDS DEVELOPMENT
Saskatchewan
Alberta
Manitoba
Heavy Oil Development
Oil Development and Processing
EDMONTON-RED DEER-CALGARY CORRIDOR
Hydro Development
Irrigation
Saskatoon Growth Centre
Red River Valley
Regina-Weyburn-Estevan Corridor
Irrigation
Irrigation
Coal-Based Energy Development
Winnipeg-Brandon Corridor
Boundary Water Use Conflicts Energy Conversion and Agriculture

ies. Conventional and unconventional petroleum extraction are expected to occur (for example, heavy oils at Cold Lake, tar sands in the Athabasca area, conventional extraction in the Pembina Valley and, if prices rise, at older sites) although there are uncertainties associated with petroleum extraction at present. Agricultural expansion is likely in the South Saskatchewan basin, based upon the growth in irrigation. The secondary manufacturing (particularly petroleum related) and service sectors will experience significant growth in the Calgary-Edmonton axis. Thermal power generation is anticipated west of Edmonton at Keephills and Genesee, and northeast of Calgary at Sheerness.

Saskatchewan's potential also focusses on energy and mineral developments (heavy oils in the Lloydminster area; uranium developments in various northern locations; and new or expanded thermal power generation at Coronach and Estevan). Expansion of the potash industry in the Saskatoon-Esterhazy belt is expected to continue. Major service centre activities will develop in Saskatoon (based on the uranium processing sector, potash, and education) and Regina (iron and steel, government and services).

Further east, Manitoba's resource and economic base will support a somewhat slower rate of growth. Power development in the Nelson basin, although already substantial, will expand to provide domestic energy as well as a significant amount for export to the United States. Agriculture will grow in the southern part of the province, particularly in the Portage La Prairie area. The manufacturing and service activities in Winnipeg will continue as a source of provincial strength.

With economic development of the region, a number of growth centres are anticipated. The major growth centres break down into two basic types: economically-diversified and resource-oriented. The economically diversified centres consist of the regional cities or regions with urban centres: Calgary-Edmonton, Saskatoon-Regina and Winnipeg. The Winnipeg area may grow westward to form strong links with a secondary centre at Brandon. The resource-oriented centres are scattered throughout the area, and development will be governed by the pace of resource exploitation. Alberta resource centres include Fort McMurray (tar sands), Cold Lake and Lloydminster (heavy oils), Lethbridge (agriculture) and Red Deer and Fort Saskatchewan (petrochemicals). Resource centres in Saskatchewan include Lloydminster (heavy oils), Esterhazy (potash), Prince Albert (paper), Estevan (coal, power generation and some petroleum extraction), and Weyburn (agriculture). Manitoba centres in the resource-oriented category are Portage La Prairie and Brandon (agricultural servicing, light manufacturing and food processing).

Development on the scale outlined above, will have a profound impact on water resources. The challenges for water managers in the region centre on mitigating the impacts of these activities, and removing possible constraints to development and diversification of the economic base. The water quantity implications of this development are associated with providing enough water to support development and providing comprehensive flood control programs in areas where economic activity is endangered by periodic flooding.

A Framework for Water Demand Forecasting

However one looks at it, water demand forecasting is a highly uncertain undertaking. There are at least two levels of water demand forecasting, a macro or regional scale, and a micro or local scale. This distinction is an important one, for it governs the selection of techniques used in the forecasting process. For example, research has shown that water use in a municipality is partially a function of prices charged for water servicing. Thus, in forecasting at the local level, pricing relationships must be an integral part of the model. However, if one considers a large river basin such as the Saskatchewan-Nelson, or even a major sub-basin within it, municipal pricing becomes a less important factor than population and economic activity forecasts. It is possible to distinguish at least four sources of uncertainty in forecasting.

First, the amount of uncertainty in a forecast increases with time. It is not difficult to show that near-term economic forecasts tend to be more accurate than longer-term forecasts.

Also, uncertainty has a spatial dimension. National level economic forecasts tend to be more accurate than regional level forecasts which, in turn, are more accurate than local level forecasts. In fact, one of the current methodological issues in forecasting is how to break the relatively more accurate upper level forecasts into their regional components.

Another uncertainty, and one which is very important in industrial forecasting, relates to the issue of technological change. Very little work has been carried out on this subject in the context of water demand forecasting. Some early work of this nature was done at the Resources for the Future Conference, but this work has not been developed to any degree. It may be possible to approach this subject indirectly through examination of a time series of survey data. Such a time series is being worked on in Canada, although it is still inadequate.

The last dimension of uncertainty is socio-economic uncertainty, that is, will the major projects expected to be undertaken actually materialize and, more important, when? What will be the growth rate of both the production and labour force for the various regional industries? Uncertainties are involved in each of these areas, as well as in several others of an economic nature which govern the preparation of water demand forecasts.

In view of the high degree of uncertainty involved in the forecasting process, methodologies must have the capacity to explore different development outlooks, or scenarios. In this sense, water demand forecasting is the process of translating anticipated social and economic projections into impacts on water use. The following discussion is aimed at the macro regional forecasting level, that is, for the prairie region as a whole.

Several overall characteristics of a regional forecasting model flow from the above discussion. First, the overall approach should be one based on the alternative futures concept. This concept requires the forecaster to assemble several different scenarios of what the region will look like at the target date. These pictures will include population size and distribution; industrial growth, change and location; agricultural expansion (or contraction) and methods; water use technology; recreational considerations; and other factors. Second, the industrial system, broadly defined, should be internally consistent with respect to its forecasts. The most common method of meeting this requirement is through the use of input-output tables. Third, the forecasting exercise should be one approached from a broad regional scale, with major effort spent in stepping down the forecasts into sub-areas. Fourth, technological change should be incorporated specifically into the model with regard both to product-process mixes and water using practices. Fifth, a large amount of effort is required in the area of probable public policy. The issue of water pricing in a municipality was raised earlier, and this particular issue might justifiably be overlooked at the macro-level. But the issue of pricing water, say, to irrigators, cannot be ignored because of the large amounts of water involved. If the future is projected merely by forecasting area to be irrigated and then multiplying by a coefficient of water use per unit of area, the economic nature of irrigation water use is ignored, price elasticity is assumed to be zero, and large errors can creep into the forecasts. This pricing issue must be addressed specifically in regional forecasts, possibly through the use of water demand curves derived from secondary data. Also in the policy sphere would be the study of likely changes in environmental control, since regulations or effluent discharge fees will probably affect the water demands of industrial plants. The model shown in Figure 3 has been designed to take these points into account.

The upper portion of the model shows the general forecasting work which has to be done prior to the actual water use analysis. As implied, the most suitable overall framework for the socio-economic forecasts is the nation as a whole, with the first part of the job being to disaggregate national forecasts to the regional level. From the regional level, one can disaggregate further to the economic region and then to the sub-basin level. This process can be repeated no matter how many alternative futures have been designed. It will be noted that regional input-output tables are an implicit part of this preliminary socio-economic work. The end result is a set of socio-economic forecasts at the sub-basin level, rationalized to both the regional and the national levels.

The middle part of the model shows where the various economic data sets fit into the individual water use sectors. It is at this level that the water use analyses enter the study. The various sectors will not be discussed at this stage except to say that the technological and policy considerations outlined earlier come into play at this level.

At the bottom level, the projected demands are brought together for a particular area and compared with available supply to identify possible shortage situations. To date, simple but reliable flow statistics have been used as measures of water supply, although possible stochastic measurement techniques would be better. If supplies are inadequate to meet demands, a variety of investigations can be launched. On the demand management side of the picture, the projection model outlined here would be useful in examining alternatives.

Current Water Demand Studies in the Prairie Region

From this outline of basic approaches to demand forecasting, it is now possible to examine analytically some of the on-going water use studies in the region. The examples are concentrated at the region-wide or basin-wide level, and are derived from federal-provincial studies, provincial studies and work done in the academic community.

The Prairie Provinces Water Demand Study (PPWD): This study, scheduled for completion in September 1982 is being conducted by the Prairie Provinces Water Board in support of the Board's mandate to examine and make recommendations dealing with water resource matters that affect inter-provincial waters in the three prairie provinces. The study is considering only current and historical water uses in the Saskatchewan-Nelson basin although, according to the terms of reference, work is to be oriented to water demand forecasting that may follow.

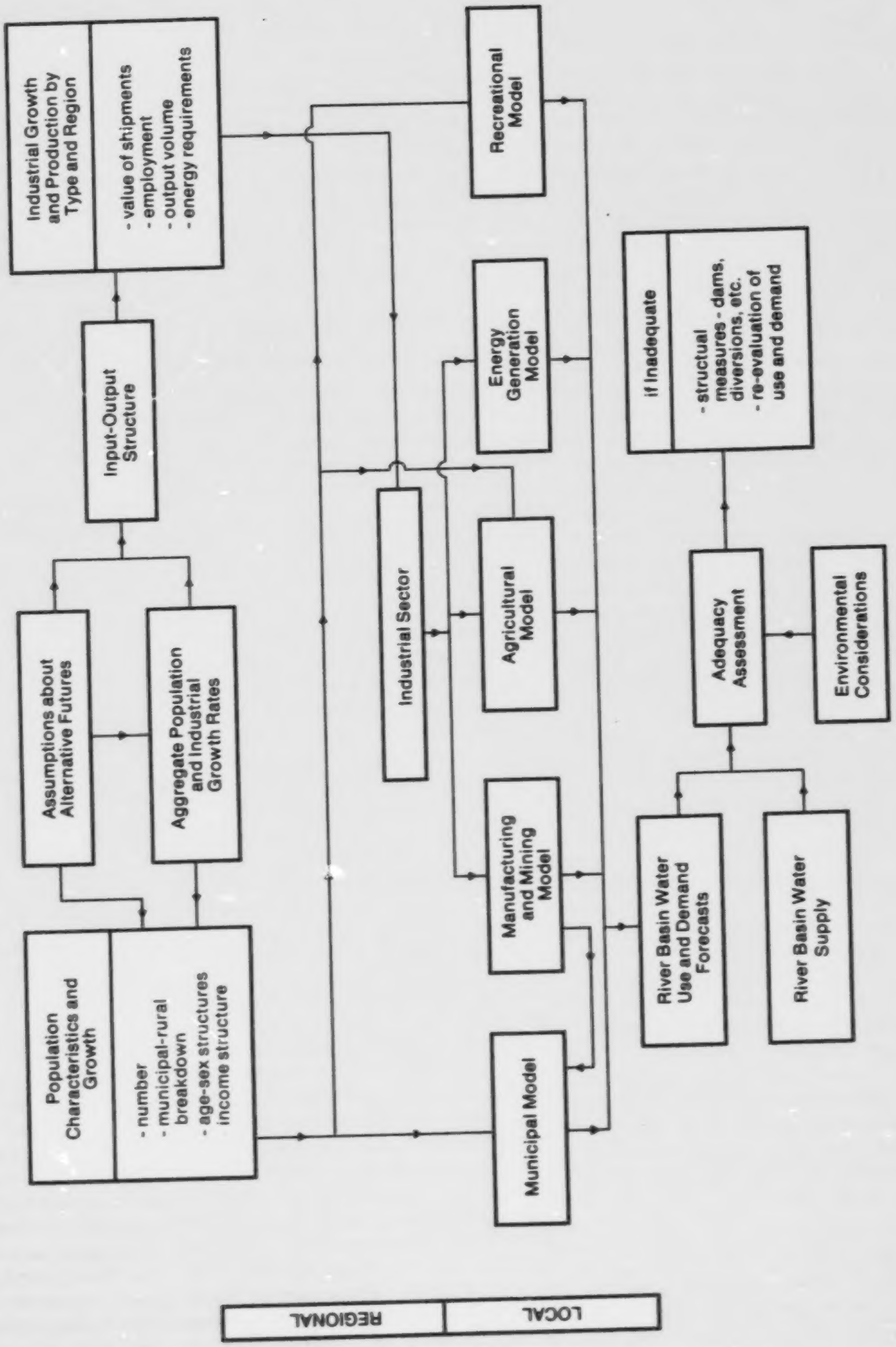
Canada West Foundation Water Resource Study (CWF): This study was conducted by a private research foundation, guided by a steering committee consisting of government, academic and private sector professionals. The study incorporated a broad overview of regional water problems (including water quality), in addition to including some forecasting of water demands. Much less data intensive than that of the Prairie Provinces Water Board, the report focussed on emerging water problems and strategic water resource management, giving an independent assessment of such measures as interbasin transfers, upstream-downstream conflicts of water use, water quality problems and other issues. The forecasting of water uses was based upon the simple extrapolation of current water use through economic trending.

Alberta Environment South Saskatchewan Planning Study (ASSP): This study exemplifies Alberta's thorough approach to comprehensive river basin planning studies for all of the major basins in the province. In terms of water demand forecasting, the study aims at determining the levels of water usage in several sectors of the South Saskatchewan basin's economy. From an assessment of the study outline, it appears that this study is the most ambitious ever undertaken in Canada, for it focusses upon not only the conventional economic production forecasts often hypothesized to underline water use, but also the economic structure of water demand, and the value of water in its various uses. This will enable the study team to determine the optimal allocation of water amongst uses and to examine the economic trade-offs implied by various water development options.

In comparing the studies, a simple chart (Table 10) has been drawn up to show the way in which each study fits into the model outlined above. In Table 10, the time perspective row shows the principal time orientation and, where available, the time horizon of each study. The basic economic data and/or forecasts row indicates briefly the general nature of the underlying economic nature of the studies (i.e. the upper part of Figure 3) and the principal variables which affect the forecasting of water uses. The activity categories row shows the major sectors covered in each study and the ways in which they were approached. The last row shows whether the studies were integrated with supply considerations.

A Case for A New Approach

It would be ideal to be able to present a range of forecasts of future water use, carefully taking into account factors such as technological change, water pricing, well thought out demographic and industrial studies, and the like. But, this is just not possible on a region-wide basis. Many small areas are under study. In addition to the three investigations mentioned, a recent University of Alberta study offers assurance that there is sufficient water in the North Saskatchewan basin to avoid shortages at least until 1985. There are also numerous planning studies. The problem is that all of these studies are un-


Population Characteristics and Growth
- number
- municipal-rural breakdown
- age-sex structures
- income structure
Assumptions about Alternative Futures
Aggregate Population and Industrial Growth Rates
Input-Output Structure
Industrial Growth and Production by Type and Region
- value of shipments
- employment
- output volume
- energy requirements
Industrial Sector
Municipal Model
Manufacturing and Mining Model
Agricultural Model
Energy Generation Model
Recreational Model
River Basin Water Use and Demand Forecasts
River Basin Water Supply
Adequacy Assessment
Environmental Considerations
if Inadequate
- structual measures - dams, diversions, etc.
- re-evaluation of use and demand
REGIONAL
LOCAL

coordinated and use different assumptions. Thus, their results are not additive. Of the major studies now on-going, all offer some promise – the Prairie Province Water Demand Study as an in-depth examination of the Saskatchewan-Nelson basin, the Alberta Environment South Saskatchewan Planning Study as a detailed look at one major sub-basin of this system and the Canada West Foundation Study as a broad overview of problems in the region. But regrettably, there is nothing comprehensive for the region as a whole.

This leads to the second point, namely, tnat the field is now ripe for study. In fact, this should be a high priority if costly errors in water management and water resource investment are to be avoided. It is necessary to find out where and in what amounts water is potentially needed. Following this, it is necessary to investigate alternatives for meeting this need – either through supply or demand management, or both. This is an urgent requirement, for development will proceed whether or not such investigations are conducted and lack of such foresight almost inevitably spells inefficient use of social resources.

Elsewhere in this Year Book, discussion centres on the value of water and on the fact that water is an economic good. Numerous research studies have demonstrated this. Being an economic good, water use is price-responsive. Studies in Calgary attest to the importance of metering and charges based on quantity used as tools for conserving water supplies. Because water is priced far below its replacement cost, the resource is unwisely used. For this reason, water shortages are almost certain in some areas, and at least short-run damage will be done to regional output.

A number of years ago, it was demonstrated that the fastest growth in water use in the United States was occurring in precisely the areas which could be termed water-short. In the ten or so years since that study, the situation has not changed. A similar situation is occurring in Canada. What is required for the drier areas is a well thought out policy of efficient water use, of allocating it to the highest valued use, and of using the price system to allocate water supplies efficiently amongst existing water uses. Before massive amounts of capital are spent diverting water from areas of more plentiful supply, water managers must investigate the "softer" management instruments of metering and pricing and other conservation measures. Water demand forecasting should be seen as an important tool in this process, and it, along with similar innovations, will help to show the way to better management of existing water supplies.

	PPWD	CWF	ASSP
Time Perspective	Current and historical water uses. Forecasting study may follow	Current and future water uses. Forecast horizon to 1985 and 2000	Current and future water uses. Forecasting horizon unspecified
Spatial Perspective	Saskatchewan Nelson Basin and its 15 component sub-basins	Three Prairie Provinces plus Northwest Territories, major basins only	South Saskatchewan River sub-basin
Basin economic data and/or forecasts	A very detailed economic base of each sub-basin, based upon analysis of census, provincial and industrial reports	Survey of available literature, including PPWD. Little primary research because of limited resources	Economic data from public and private agencies, augmented by research done for the study
Approach to water use forecasts	Uncertain, as study not yet designed. Probably use of a simulation model to examine alternative futures	Time trending; use of alternatives uncertain in material available to date	Consideration of a large number of variables affecting water use, including economic variables. Heavy concentration on irrigation
Approach to the economic aspects of water use	Not determined as yet. Current use study is employing overall community water charges where applicable as an indicator of pricing factor	Limited qualitative work and assessment, but no research on demand curves, etc.	Simulation of alternative futures, and attempt to define the economic nature of water use. Also, studies of water value in alternative uses
Activity categories	Municipal, industrial, agriculture, recreation, power generation, environmental considerations	Municipal, industrial, flooding power, navigation, fish and wildlife, recreation, environmental protection	Agriculture, municipal, industrial, electrical energy, fish management, wildlife, recreation, water allocation
Overall purpose	Companion to Saskatchewan-Nelson basin water supply study	Private research body's assessement of regional water problems	Demand studies part of a comprehensive basin planning study

During the 1960s, it was becoming apparent that water demands were increasing rapidly and that water pollution was a significant threat to the health and well being of Canadians and to the quality of the environment. At that time, federal water activities were still restricted mainly to major structures to control levels and flows. A new federal approach was required.

In 1967, the federal Minister responsible for coordinating water programs extended an offer to some of his provincial counterparts to finance a pilot exercise in river basin planning in each of the major regions of Canada. The principles underlying the new programs were subsequently embodied in the Canada Water Act, which became law in 1970.

To date, the Canada Water Act has been in force for some twelve years during which a significant number of river basin planning and implementation programs have been conducted throughout Canada. Notwithstanding this fact, a number of factors have entered the scene to cause a reorientation of water planning and management programs in recent years. A continuing shift from the comprehensive basin approach to both issue-oriented and framework investigations is occurring, and the impetus of the Flood Damage Reduction Program and other programs associated with federal responsibilities in interprovincial waters are now accounting for more of the activities formerly undertaken under river basin planning and implementation.

These facts were revealed in a report by an evaluation team established to determine the effectiveness of joint river basin planning and implementation programs over the period 1975-1980. Much of the following discussion originates from that report.

Federal-Provincial Water Resources Planning

The first basins selected for study in the late 1960s were the Saint John (New-Brunswick), Qu'Appelle (Saskatchewan and Manitoba) and Okanagan (British Columbia). These pilot planning agreements were undertaken jointly in an effort to overcome, by federal-provincial cooperation, the jurisdictional limitations of both levels of government; they were comprehensive in scope, included reference to all water uses, and gave greater emphasis to social needs and environmental implications; and they were basin-wide to both reveal and relate the causes and effects of modifying the water regime. Not only were the studies to involve local residents actively, but they were seen also as a way of providing a basis for developing planning and evaluation skills and tools that could be transferred to other basins.

From their beginnings more than a decade ago, water management programs have represented a substantial change from earlier programs. Looking beyond engineering measures to alternate courses of action (including the non-structural), inviting public involvement, estimating future needs and assessing environmental consequences, all of these changes complicated the process of determining an appropriate plan but also educated managers to a range of concerns, improved their skills and made them more sensitive to socio-economic and environmental effects. At the same time, the public gained an awareness of the real cost of choices and of the limitations of nature's resiliency. For many, it gave an insight into water problems and removed a tendency to suggest easy answers.

Better federal-provincial relations have resulted from these exercises, owing to the shared nature of tasks and the consensus-forming nature of joint planning boards and committees. The provinces have benefitted in the provision of useful information to apply to other regions of their respective jurisdictions or to subsequent problems, and in the way the programs have encouraged them to adopt changes in their laws and institutions. It is apparent that the programs have been a vehicle of change and of new perspectives in water management and will leave a lasting impact among provincial agencies and basin residents. Savings in capital costs seem to have been facilitated through the more comprehensive evaluations of solutions. Examples are the rejection of costly water importation to the Okanagan Basin in favour of an extension of lake storage range, and the finding of the St. Lawrence Water Quality Study that secondary treatment of Montreal's waste effluent would be less beneficial than the control of toxic chemical wastes and the careful siting of industrial discharges.

The results of the early efforts were encouraging but not all positive. Detailed comprehensive investigations of relatively small basins like the Okanagan have been costly in terms of both time and resources, and were often insufficiently responsive to pressing issues requiring more specific attention. At the same time, the zeal for planning often masked the necessity for providing a politically and institutionally sensitive, as well as explicit, strategy to implement the recommendations of the study. For these reasons, and because of the unfocussed collection of data and the inflexibility of comprehensive studies and long delays before action is taken, interest in the comprehensive planning exercise has been waning. The focus of activities in water resources planning gradually has become more action-oriented, aimed at the resolution of specific and immediate water management problems. Some examples include water quality oriented studies (St. Lawrence and English-Wabigoon River basins), environmental impact studies (Lake Winnipeg, Churchill-Nelson and Churchill-Saskatchewan), those related specifically to the impact of encroaching urban development (Shubenacadie-Stewiacke and Waterford), and to flow regulation (Ottawa).

Towards the mid-1970s, it was recognized that there will be cases where a full comprehensive approach may be warranted, but that the study focus could be improved by first conducting a limited preplanning study. When preplanning was not done or not done well, the studies tended to lack focus and progressed slowly. As now envisaged, preplanning studies help to define in detail the water resource management concerns and opportunities and the capability of existing data sources and analytical techniques to resolve those concerns. Formal planning studies, if deemed necessary, can then be directed to the resolution of identified, specific management concerns. This route has been followed for the Mackenzie, Lower Saskatchewan, Thompson and Yukon basins in western and northern Canada, and is being followed for the Winter River basin in Prince Edward Island.

In yet another variation within the planning process, the vast Mackenzie River basin and the adjacent Yukon River basin recently became the focus of framework planning studies, with the objective of adding to existing knowledge of the water-related environment. In this way, when subsequent specific proposals for economic development arise, there will be other options and better understanding of ecological and social impacts available to weigh them against. British Columbia, Alberta, Saskatchewan and the Yukon and Northwest Territories all have a stake in the Mackenzie study which focusses on sensitive areas, hydrologic modelling, spring flooding, and the kinds of impacts likely to result from mining, pipelines, highways, dredging, and hydroelectric developments. The federal, British Columbia, and Yukon governments are conducting the Yukon River study to gain similar information. Such studies as these could have provided the wherewithall to avoid the unforeseen but disastrous downstream effects on the Peace-Athabasca Delta in the late 1960s in the wake of regulating the headwaters of the Peace River.

Many basins and issues with variations on these characteristics have been subjected to the cooperative federal-provincial process. Table 11 indicates the range of such activities between 1976-1981 in terms of preplanning, planning and implementation and also indicates the nature of the activity - comprehensive, water quality, framework and others. Not reflected in the table are federal-provincial activities under the national Flood Damage Reduction Program, which are dealt with elsewhere in this edition.

Federal-Provincial Planning Implementation

Implementation of recommended plans is viewed as a phase separate from planning. It may be carried out as part of regular ongoing programs at the federal and provincial levels without the benefit of a formal agreement (for example, the Saint John basin) or, if required, separate federal-provincial cost-sharing agreements are negotiated, as in the case of the Okanagan, Qu'Appelle and Souris basins. At times, a province may proceed on its own with implementation following a joint planning study, as is happening in Quebec with St. Lawrence Water Quality implementation.

The evaluation team noted that not all planning recommendations are implemented. For that matter, some recommendations in planning reports often are never expected to be implemented. They are included primarily to make people think about alternatives and implications without expecting any concrete action to occur. It also was noted that over the two to five year period of a planning study, a good number of the recommendations which are seen to be emerging may be implemented before the planning phase is concluded. Thus, when action is taken during the planning stage, there will be no observable response to such action during the implementation stage. The key issues are not how many recommendations are subsequently implemented, but rather how effectively problems are being resolved.

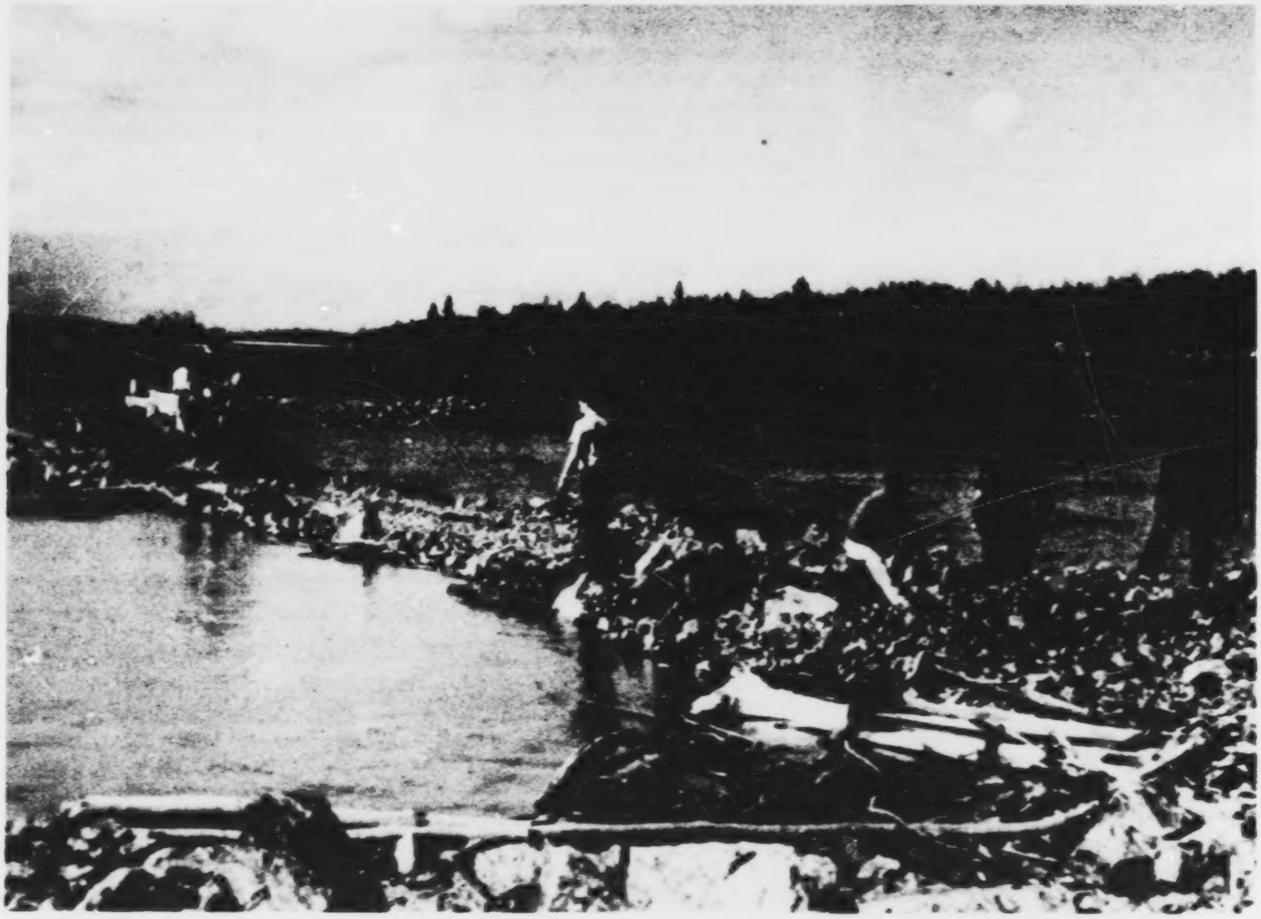
A concern has been voiced regarding the apparent delay between the conclusion of the planning phase and the commencement of implementation. This waiting period has been as long as two years, and many believe that such a delay causes the enthusiasm and momentum which were built up during the planning phase to be lost. But this delay involves a tradeoff which must be recognized. The time between planning and implementation is required to

	Preplanning	Planning	Implementation
Comprehensive	Lower Saskatchewan (1974-79) Thompson (1979-80)	Shubenacadie (1977-80) Souris (1974-78)	Okanagan (1976-82) Qu'Appelle (1975-84) Souris (1979-)
Water Quality		Lake Winnipeg (1977-deferred) Ottawa (1979-81) St. Lawrence (1974-76) English-Wabigoon (1976-81)	
Framework	Yukon (1978-79)	Mackenzie (1978-81) Yukon (1980-83)	
Other	Winter (1977-)	Fraser Estuary (1978-81) Ottawa (1977-80) Waterford (1980-85) North Shore Rivers-Quebec (1978-83)	

examine and debate the nature and costs of the recommendations. In a system where elected officials are accountable for their decisions, time is required for review and assessment. Taxpayers would be alarmed if they thought that the implications of committing substantial amounts of capital and labour were not appraised carefully.

A further cause for delay lies in the fact that water and water-related responsibilities are not all vested in one federal or provincial department. As a result, negotiations on the federal side alone could involve not only Environment Canada, but also Fisheries and Oceans, Indian and Northern Affairs, Canada Mortgage and Housing, and Regional Economic Expansion. Unless they formed part of the planning phase, they would not always be receptive to planning recommendations likely to emerge that would influence their other departmental priorities. However, coordination through the Interdepartmental Committee on Water is keeping all federal departments abreast of water happenings at key stages in order to overcome this problem.

Where several federal departments are involved in a multiple planning program, ex-



The earliest implementation project under the Canada Water Act was designed to alleviate the low water conditions affecting the Peace-Athabasca Delta in the early 1970s.

perience has shown that separate federal-provincial agreements should be negotiated at the implementation stage to enable the various groups to work as independently as possible. The independent operation is seen to result in less interference in scheduling between two or more different groups.

The evaluation team notes that effective handling of resource needs and flexibility are important requisites for the implementation stage. If an implementation agreement does not provide sufficient resources, then the implementors will experience difficulty. Also, more flexibility is needed over budget allocation during implementation to allow program managers to respond to problems which emerge after completion of the planning phase.

Future Trends in River Basin Management

While it is always risky to speculate on what the future may hold in store, it is possible to extrapolate some recent trends a few years into the future.

One trend that is expected to continue throughout the next decade is a further concentration of the federal effort on international and interprovincial river and lake systems. Notable exceptions are likely to be an acceleration of assistance for water development related to regional economic expansion, and water resource planning related to northern development.

In dealing with international basins, the emphasis will be on defining numerical values of quality and quantity of waters that will protect the interests of the downstream country, and serve as a reasonable constraint on the upstream neighbour. Joint international planning per se will continue to be avoided. While both Canada and the United States will engage in intergovernmental basinwide planning, each country will retain the right to choose its own goals and means, and be constrained only by the impacts it has upon its neighbour.

Basin planning in the future is likely to see a combination of studies addressing specific problems, and more comprehensive approaches. However, one is unlikely to see comprehensive studies undertaken without some measure of preplanning. Also, even in cases where broadly based planning studies are carried out, the trend likely will be towards sectoral implementation agreements to permit more efficient delivery.

The problem of balancing water supply and demand is likely to intensify. Major energy supply areas are located in river basins which have significant water problems such as too little water, fragile ecosystems and populations which depend upon in situ use of water. There will be increasing pressure to expand irrigated acreage in generally water-short areas of the West. Even in the Great Lakes region, conflicts will begin to emerge between consumers and in-situ users. In many of these cases, the implications will extend beyond provincial and perhaps even national borders, and will require early planning.

Another area likely to see an increasing emphasis is research on the instruments of demand management such as pricing, rate structuring, and water conservation measures. Within one or two decades, demand management could become a full-fledged equal to supply manipulation in developing or expanding water services. Increasing emphasis in this area will likely go hand in hand with improvements in the ability to forecast future water demands, and with more planning for the conjunctive use of surface and ground water.

In terms of streamflow regulation and apportionment, current semi-permanent interjurisdictional arrangements in areas like the Great Lakes, Columbia, Lake of the Woods and Saskatchewan-Nelson areas are likely to be expanded into such major Canadian basins as the Ottawa and Mackenzie and additional Canada-U.S. rivers. Water quality studies are likely to be aimed more and more at identifying the source and pathways of specific contaminants, for example mercury in Northern Manitoba, and water quality objectives will be used increasingly as a means of addressing interjurisdictional water quality issues. Current flood risk mapping efforts are likely to result in renewed demands for major flood control projects as new development is constrained in identified high risk areas.

The next few years will likely see a continuation of inflationary pressures, restricted government spending, and greater government accountability, which have already impacted upon basin planning activities. Because this will result in more carefully defined studies, it will become even more important at the start to make sure that, from the public's perspective, the critical issues and problems are being addressed. Public preferences may acquire a greater weighting in making the difficult tradeoffs between environmental quality and other social priorities.

There is room for improvement in public consultation advisory techniques, in developing better weighting systems for conflicting interests and in educating planners and the public in involvement/information techniques. The federal government is undertaking several initiatives to make itself more open, responsive and effective in meeting public concerns, namely, the Access to Information and Privacy Bill and the development of public consultation policies by several departments. Environment Canada has met with approximately 200 public interest groups across Canada to develop a public consultation policy, the cornerstone of which is the holding of annual national and regional meetings to discuss matters of mutual concern to the public and the department. In many cases, the provincial governments are undertaking similar initiatives. In other words, the attitude is evolving that public consultation, whether at the policy or project level, is "a way of doing things". This should create a better climate to heightened public awareness and receptiveness in all resource and environmental programs, including river basin management.

There is, then, an evolution in the planning process which began under the Canada Water Act in 1970. Planning, which a decade ago might have fallen within the purview of river basin management, is being increasingly accounted for under the Flood Damage Reduction Program, and Canada-U.S. and Interprovincial programs. This appears appropriate inasmuch as most of the joint planning and implementation exercises under way involve interprovincial or direct federal interests. The process is being allowed to evolve as it is now taking place, with some minor adjustments to complement the process. One adjustment will probably see a more precise definition of the issues, time and resources required at the preplanning stage in order to shorten planning periods and improve the chances of implementation. Finally, public consultation is expected to grow in importance as the complexity of water issues increases and water begins to command more and more attention as a basic resource.

Over the past three decades, federal policies and the federal role in the water resources field have expanded to meet federal responsibilities in harmony with provincial water policies.

In the 1950s, the federal government participated with the provinces in numerous flood control projects. This role was formalized through the Canada Water Conservation Assistance Act (1953) which gave federal authorities a technical say on how flood control money was to be spent. The Act included provision for engineering and benefit-cost evaluation of provincial proposals. It was limited to major flood control works, however, and did not deal with a federal planning role in multiple-purpose water use, nor did it allow flexibility in cost-sharing arrangements.

In the late 1960s, environmental and resource conservation matters were placed high on the political agenda. With multiple-purpose planning, the federal and provincial governments had to join together to meet their respective responsibilities to monitor, plan and manage the nation's water. To fulfil this role properly, the federal government enacted the Canada Water Act in 1970.

The new legislation provided for joint consultation between federal and provincial governments in matters related to water resources. It enabled the federal government to participate in comprehensive river basin planning and water quality management in major river basins across Canada in proportion to federal responsibilities.

At about this same time, the effects of eutrophication in natural water bodies were being viewed as a serious national problem. Because phosphorus from laundry detergents was known to be a principal cause of the problem, the regulations to control the amount of phosphorus in laundry detergents, the first step in the eradication of this problem, were included under the nutrient control provisions of the Canada Water Act.

The primary responsibility for administering the new Act was vested in the Department of the Environment upon creation of that department in 1970. Many federal-provincial shared-cost programs have been developed since 1970 under the Canada Water Act. A map inside the back cover illustrates current activities under the Act.

The federal government spends about $12 million annually on federal-provincial shared-cost programs under the Canada Water Act. This fund had a fixed ceiling of $18 million per annum in fiscal year 1976-77, but this has since been reduced to $12 million. Estimates suggest that as much as $23 million would be expended annually if the federal government were to respond positively to all provincial requests for joint programs. This restraint on the part of the federal government requires that projects be chosen more selectively and that resources be spent more efficiently than heretofore.

Although most federal-provincial agreements carry a time limit within which the objectives of the agreement are likely to be reached, there are some agreements involving monitoring, and survey responsibilities which are projected to continue into the foreseeable future. An example of this is the program of the Prairie Provinces Water Board, which is described later in this section. Another is the Water Quantity Survey Program which the federal government has been involved with since the late 1800s. This program was operated under informal arrangements with the provinces until April 1, 1975, at which time ongoing cost-sharing Water Quantity Survey Agreements were implemented with all provinces and with the Department of Indian Affairs and Northern Development for the territories. It is recognized that water quantity data are essential to water management and, since the costs of collecting water data are substantial, the efficiency of data collection programs is enhanced significantly by combining networks and standardizing methodology. These Agreements recognize that water quantity data may be collected to meet federal needs, provincial needs, or a combination of needs. Hence, funding for the operation of the networks is provided according to each party's needs. The water quantity networks and cost-sharing data are determined annually by Federal-Provincial Coordinating Committees.

The federal and provincial governments also operate networks for the monitoring of water quality parameters. At the request of several provinces, an assessment is now under way to determine the advisability of negotiating federal-provincial agreements in this area as well.

With the passage of the Canada Water Act, and even in anticipation of the Act in the 1960s, activities in water resources planning began to increase rapidly in all regions of Canada. Examples of studies and their completion dates are: Peace-Athabasca delta (1972); Saskatchewan-Nelson basin (1973); Okanagan basin (1974); Flow Regulation – Montreal Region (1976); and Northern Ontario Water Resources (1978). On the basis of experience to date, it is apparent that the venture by governments into joint water resources planning has been successful. This success points up the need for continuing joint federal-provincial studies designed to protect the environment, improve or maintain water quality and still achieve social and economic potentials.

Implementation of a study's findings can take various forms. It is sometimes possible to solve the problems and achieve the opportunities identified through use of existing federal and provincial programs. Where specific implementation agreements appear warranted, full use of federal and provincial programs is anticipated, with due consideration being given to the priorities of the agencies administering such agreements.

A relatively new innovation in recent years is the preplanning study. The preplanning study arises as a result of public representation to resolve one or more problems which are perceived at the local level. It has become the vehicle with which to not only investigate the concerns expressed, but also to examine briefly all of the emerging and potential opportunities and problems of the area in question and to make recommendations as to the desirability of a longer-term planning study.

A brief review of federal and federal-provincial preplanning, planning and implementation programs currently ongoing in Canada is given, by province, below. Included are several flood prevention programs of varying magnitudes but not the Flood Damage Reduction Program that is described elsewhere in this Year Book.

The Water Quantity Survey Program was operated under informal arrangements with the provinces until 1975, at which time cost-sharing agreements were implemented with each province.

Atlantic Provinces

Marsh Creek: In September 1977, Canada and New Brunswick entered into an agreement to reduce damages from floods in the Marsh Creek watershed, which lies within the City of Saint John. From December 1974 to September 1977, the City experienced damaging floods on three occasions as a result of high intensity rainfall. Development in the watershed had reduced the natural floodway, with the result that peak flows, runoff and flood damages all increased. The agreement has offset this through acquisition of floodprone land, construction of flood control reservoirs, channel improvements, and changes in structures. This work is to be completed in 1982. The $2 010 000 in costs are being shared equally by the federal, provincial and municipal governments.

Shubenacadie-Stewiacke Basin: A Study of this basin was undertaken in 1977 to examine critical problems affecting the basin's water resources, and to develop a comprehensive framework plan focussing on water quality and quantity objectives and complementary development and resource use strategies. The basin is not only the largest in Nova Scotia but it encompasses a region important for agriculture, mining, forestry and recreation. The study has been completed and the final report was released in 1982. The $730 000 costs of the study were shared equally by the governments of Canada and Nova Scotia.

Waterford River Basin: A study of the Waterford River basin was initiated by Newfoundland and Canada in 1980 to examine the effects of urbanization on the water resources of the basin, and to develop criteria for urban development which minimize impacts. No federal funds have been encumbered for this study. The province of Newfoundland has provided funding of $205 000, while the federal share, half of the total input, will be in the form of work sharing.

Quebec

Dykes and Flow Regulation Works – Montreal Region: Between June 1974 and October 1976, a study was conducted to determine the means of reducing the frequency of both flooding and extreme low water levels in the Montreal region water bodies. The Committee on Flow Regulation, which conducted the study, submitted an interim report in 1975 containing specific recommendations. The extensive damage from flooding in 1974 and 1976 in the region made it important that these recommendations be implemented as soon as possible. As a result, a Federal-Provincial Implementation Agreement was signed in October 1976, just as the Committee's Final Report was released; this Agreement pointed to the need to plan and construct dykes to prevent flooding in the municipalities of Pointe Calumet, Sainte-Marthe-sur-le-Lac, Roxboro, Pierrefonds and Châteauguay, and to determine the feasibility of 1) enlarging the storage capacity in the upper Ottawa River basin, and 2) reducing the maximum flows of Rivière des Mille Iles.

Construction of dykes at Roxboro, Pierrefonds and Point Calumet has been completed while similar work at Saint-Marthe-sur-le-Lac is nearing completion. Following a series of provincial public hearings concerning additional storage capacity in the Quinze Reservoir, the province has indicated that it does not wish to pursue the option of increasing storage in that reservoir. Studies have indicated the economic feasibility of a control structure on the Rivière des Mille Iles. If the control structure is installed by 1984, as expected, $16 million will have been spent, with the federal government providing 45%, and the province and municipalities, the remaining 55%. The combination of structural works should lessen the recurring flood damages around Montreal; the non-structural policies agreed to by the senior levels of government should ensure minimal construction on the region's floodplains in the future.

North Shore Rivers Ecological Inventories Program: Quebec and Canada signed an Agreement in 1978 to conduct joint ecological studies of rivers which lie to the east of the Manicouagan-Outardes basins and flow into the St. Lawrence River from its north shore. These studies are intended to facilitate future assessments of ecological impacts from major developments. Studies and geographical inventories have been completed on the Romaine and Natashquan Rivers and were continuing on rivers to the east of the Natashquan River basin. By the end of the program in September 1982, the two governments will each have contributed $1.22 million.

St. Lawrence Water Quality Study: In 1972, the Canada-Quebec Working Group identified pollution in the St. Lawrence River as a serious problem affecting municipal and industrial water supply, fisheries, wildlife, recreation and tourism. This led in 1974 to a Canada-Quebec Agreement to develop a comprehensive water quality plan for the river from the end of the international section near Cornwall, Ontario, down to the Gulf of St. Lawrence. The study was completed and the Final Report presented in June 1978 at a shared cost of $4 million. The study has succeeded in identifying the general water quality regime in the river and the uses dependent upon it, the types of degradation occurring, and the measures necessary to protect, improve and restore the water's quality. The study revealed that toxic substances are a major problem.

Quebec-Ontario

Ottawa River Regulation Planning Committee: This Committee, consisting of Ontario, Quebec and federal members, was formed in 1977 out of the need to give consideration to recommendations from the Committee of Flow Regulation – Montreal Region, which was implementing a program to reduce the frequency of extreme (low and high) water levels in the Montreal region. The Environment Canada Minister invited interested federal and provincial departments and heads of agencies to participate in the Committee; their mandate was to plan and recommend criteria for regulating the Ottawa River, taking into account hydroelectric operations, flood protection, navigation, low water problems, water quality needs and recreation. The Committee's Final Report containing recommendations for regulating the Ottawa River was released in December 1980. A major recommendation is the setting up of a permanent regulating body which would liaise closely with the St. Lawrence Regulation Board. Also, the Committee developed a mathematical model from which forecasts on a real-time basis are being provided daily for the principal reservoirs in the Ottawa River basin and at selected points where flooding takes place. A flood warning system also has been developed. At this writing, the Committee's mandate has been extended to provide continuity of operation in anticipation of the establishment of a permanent Canada-Ontario-Quebec body with responsibilities for coordinated operation of principal reservoirs in the Ottawa River basin.

Technical Working Group on Water Quality in the Ottawa River: In 1976, a Working Group, consisting of representatives from the federal, Quebec and Ontario governments, was formed to review existing pollution control programs in the Ottawa River basin and to identify additional measures for government consideration. The Group's report (1978) highlighted the importance of completing the Hull-Outaouais regional sewage collection and treatment system, and also indicated that substantial progress had been made in cleaning up discharges to the river. A year after its 1978 report, the Working Group was reconstituted. Its terms of reference were limited to an investigation of nutrients, contaminants and bacteriology, based principally on existing data. The Group submitted its report early in 1982, recommending the establishment of a federal-provincial committee to review and implement an acceptable coordinated monitoring plan for the river. The details respecting implementation are being finalized by the three governments.

Ontario

Canada-Ontario Agreement on Great Lakes Water Quality: This Agreement was initially signed in 1971 and renewed in 1976 to provide a basis for implementing the Canada-U.S. Agreement on Great Lakes Water Quality. It achieves this by coordinating and implementing federal and provincial input in order to discharge Canadian responsibilities under the Great Lakes International Surveillance Program, and by conducting pertinent research. At this writing, the 1976 Agreement has expired and necessitated an exchange of letters between Ministers extending the expired Agreement. A revised Agreement, expected to be finalized in 1982, will reflect the new Canadian commitments under the 1978 Canada-U.S. Agreement.

One of the major goals of the first Canada-Ontario Agreement (1971) was the control and treatment of sewage from municipalities. Since 1971, the cost of the municipal sewage treatment program in the Great Lakes region of Ontario has totalled over $1.7 billion, of which the provinces and municipalities contributed $1 billion. A more substantial story describing the cleanup of the Great Lakes appears elsewhere in this Year Book.

English-Wabigoon River System: This northwestern Ontario river system underwent study during the period 1978-1980 to evaluate methods to reduce high mercury levels affecting the system. The Canada-Ontario study focussed on ways in which mercury travels, or is deposited and retained within the river system, as well as on methods to reduce the absorption of mercury by fish and other water life. The $300 000 in project costs was shared equally by the two governments. Related studies outside the Agreement were undertaken by both governments, including engineering and economic evaluation of measures selected to reduce mercury contamination, and a shoreline study to determine potential sources of mercury.

Prairie Provinces

The Prairie Provinces Water Apportionment Agreement: In the past, the problem of divided political jurisdiction over river basins within the prairie region has been a major constraint in the development of long-range comprehensive water management plans. Particularly difficult is the management of the Saskatchewan-Nelson basin, which covers a large part of the settled area of all three provinces. The Prairie Provinces Water Board was created in 1948 to determine the best use of the basin's waters, but was initially unable to develop long range development objectives acceptable to all parties concerned. However, in 1969, the three provinces and the federal government signed the Prairie Provinces Water Apportionment Agreement, which reconstituted the Prairie Provinces Water Board and provided for the equitable apportionment of all eastward flowing waters among the three prairie provinces. The federal government finances 50% of the operations of the Board.

This Agreement ensure one half the natural eastward flow of waters arising in or flowing through Alberta, for Saskatchewan, and one half the eastward flow arising in or flowing through Saskatchewan, for Manitoba. Under the Agreement, the Board has undertaken a study to report on historic and current water uses in the three prairie provinces, for release in 1982. Among other responsibilities, the Board has been studying apportionment implications of westward flowing streams, and has recently become involved in establishing commonly accepted cross-sections or profiles to describe ground water conditions at provincial boundaries.

The Qu'Appelle Basin Agreement: The Canada-Saskatchewan-Manitoba Qu'Appelle Basin Study, completed in 1973, developed a comprehensive framework plan for the development and management of water resources of that basin. In 1974, a 10-year DREE Agreement was signed to implement the study recommendations. By the end of March 1984, some $18 000 000 will have been contributed at the federal level and another $15 700 000 by Saskatchewan carrying out such diverse projects as flood control works for Regina, Lumsden, Tantallon and Moose Jaw; works to increase the conveyance capability of the Qu'Appelle River; Master Plans for tourism and recreation development for the Qu'Appelle Valley; and fisheries and wildlife conservation projects.

The Lake Winnipeg, Churchill and Nelson Rivers Agreement: In 1971, the federal government and Manitoba signed a three year, $2 million Agreement which provided for studies to determine the effects that regulation of Lake Winnipeg, diversion from the Churchill River and the development of hydroelectric potential of the Churchill River diversion route are likely to have on water and related resource uses. The study released in 1975 with a comprehensive list of 47 recommendations for implementation, thirteen of which are directly related to federal interests.

Manitoba Hydro and various Manitoba departments have been implementing some of the Study Board's recommendations that are provincial responsibilities. The Freshwater Institute, in the federal Department of Fisheries and Oceans, is continuing its major research project on the fisheries of South Indian Lake. Environment Canada is continuing its monitoring of water quality and quantity (including sediment). With mercury contamination now recognized as a potential environmental problem within the Churchill-Nelson Project boundaries, monitoring studies, pathway studies and mitigation studies have been proposed to develop knowledge on mercury contamination within waters of the Churchill-Nelson Project. Native demands for remedial measures, including studies, have been formalized by an arbitration process under the Northern Flood Agreement (1977) signed by Manitoba, Manitoba Hydro, Canada and the native peoples of northern Manitoba.

Red River Basin: In January 1981, a Canada-Manitoba Ad Hoc Task Force on Manitoba Flood Mitigation Projects issued a report recommending that upgrading of ring dykes around eight communities

(Emerson, Dominion City, St. Jean Baptiste, Morris, Rosenort, St. Adolphe, Brunkild and Letellier) was both feasible and desirable. The $4.5 million in costs would be shared by Canada, Manitoba and the local municipalities. Work is scheduled to begin in 1982, and be completed by 1985.

Souris River Basin: A Planning Study to formulate a framework plan for the management of tne water and related resources of the Souris basin was conducted by the Canada-Saskatchewan-Manitoba Souris River Basin Board during the period 1974-1978. The Boards Final Report was released in August 1978, and both an Advisory Committee on Implementation and a Souris River Study Implementation Working Group were established. The Advisory Committee on Implementation has suggested that the majority of the recommendations can be undertaken under existing federal programs, provincial programs, federal-provincial agreements and proposed federal-provincial agreements. In particular, a number of the recommendations concerned with water supply and flood damage reduction are already included in the Canada-Saskatchewan Subsidiary Agreement on Water (under the DREE General Development Agreements).

British Columbia

Fraser River Basin: Two Canada-British Columbia Projects are currently under way in the Fraser River basin.

In 1977, the federal and British Columbia Environment Ministers authorized a preliminary assessment of the need for a Fraser River Estuary Study which would develop a management plan and recommend implementation measures for the estuary that would ensure a balance between economic and environmental interests. In 1978, several reports were produced describing the prospects for the area and laying out existing policies and practices governing utilization of the estuary. A two-year, $300 000 study agreement was signed in 1979 authorizing the setting up of a Fraser River Estuary Planning Committee. Four federal-provincial task forces were established to coordinate program activities. At this writing, the study is coming to an end. An interesting aspect of the study is the broad public participation required by the agreement.

The Fraser River valley has had a long history of destruction and costly floods. To offset this, the Fraser Valley Flood Control Program was begun in 1968, specifically to provide protection from flooding of land in the lower reaches of the valley by rehabilitating dykes, constructing new dykes, increasing river bank protection, and improving internal drainage facilities. Over the years, the expiry date of the study has had to be extended and the funding increased. The present funding level is $60 million for each government, and the agreement now extends to March 1984. Local authorities are responsible for providing all necessary rights-of-way and for operation and maintenance of the completed works.

Thompson River Basin: In May 1979, the federal and provincial governments signed an agreement authorizing a Task Force to conduct an eight-month preplanning study of the Thompson River basin at a shared cost of up to $60 000. The Task Force submitted its report in February 1981, recommending that hydrometric data be collected immediately to increase the background information on surface water hydrology. The report also recommended immediate action to extend research on the impact of phosphorus on algal accumulation. Over the longer term, the Task Force recommended a three-year, $2.4 million planning study which would seek to find means to allocate the limited water resources among competing interests, while improving water quality.

Okanagan River Basin: A Canada-British Columbia Study Agreement conducted between 1969 and 1974 produced a comprehensive plan for the development and management of the Okanagan Valley's water resources. In 1976, a $5 million implementation program was agreed upon to carry out the study recommendations. Under the new Agreement, which ends in 1982, Canada and British Columbia are sharing the costs for all works, including improvements and modifications to flood works; modifications to the Kelowna floating bridge; improvements to existing water intakes and recreational facilities, and modifications to the river intakes, and development of waste treatment facilities. A major water quality monitoring program was conducted to access the effectiveness of remedial actions undertaken to reduce phosphorus loads to the main valley lakes.

Northern Canada

Mackenzie River Basin: Planning for Canada's largest river basin began in 1972 with the establishment of a continuing committee representing Alberta, British Columbia, Manitoba, Saskatchewan and the federal departments of Environment, Indian and Northern Affairs and Transport. In 1977, the Committee was reconstituted under a formal Memorandum of Understanding and empowered to undertake a $1.6 million study of the water and related resources of the basin. The study report was published in 1982 and its nine recommendations are being addressed by the Mackenzie River Basin Committee and the governments involved, including the governments of the Northwest Territories and the Yukon. The main recommendation is for the negotiation of an agreement on the management of interjurisdictional rivers.

Yukon River Basin: Water officials in the basin were becoming concerned with conflicts which were developing among water users in the basin. A preplanning study in 1978-1979 identified new resource development initiatives in the field of energy, transportation, mining and recreation, and outlined decisions and studies required to assess alternative uses of water, conflicts and associated impacts. A three-year basin planning agreement was signed in November 1980 to undertake studies leading to a planning framework under which potential development alternatives in the basin can be evaluated. The $2.2 million costs of the agreement are being shared as follows: Canada 90%, Yukon Territory 5% and British Columbia 5%.

Dyking has formed an important part of the $120 million Fraser River Flood Protection Program

Canada and the United States share a common boundary extending from the Atlantic to the Pacific and, in the north, along the Alaskan peninsula to the Arctic Ocean, a total length of some 8 850 km. Over this distance it passes along a number of major rivers and lakes and intersects many rivers which flow across the boundary. By the turn of the Century, it was becoming apparent to government leaders that some permanent provisions should be made for dealing with a number of complex water problems that were developing. After lengthy negotiations, the Boundary Waters Treaty was signed in 1909 and was ratified eighteen months later. The Treaty sets out the rules and principles which govern the use and development of the water resources of common interest to the two countries.

The International Joint Commission (IJC), which consists of six members, three from each country, was established under the terms of the Treaty. The Commissioners act, not as separate national delegations under instructions from their respective governments, but as a single body seeking common solutions in the joint interest and, most importantly, in accordance with the agreed rules or principles set out in the Treaty. The IJC's responsibilities under the 1909 Treaty fall into three general categories – regulatory, investigatory and surveillance coordination.

Regulatory responsibilities involve the exercise of quasi-judicial powers in approving or withholding approval of applications for the use, obstruction or diversion of waters on either side of the boundary that would affect the natural level or flow on the other side. In granting such approval, the IJC may, and in certain cases must, impose conditions to ensure that suitable and adequate provision is made for the protection and indemnity of all interests on the other side of the boundary that may be injured by the approved use, obstruction or diversion.

The IJC's investigatory responsibility pertains to questions or matters of difference along the common frontier which are referred to it by either or both governments. The reports of the IJC in such cases are not regarded as decisions in law; rather, they are simply recommendations to the two governments by a neutral body. The governments decide whether or not these recommendations will be accepted or acted upon. However, the IJC's reports are highly influential because they are public documents and have the weight of public opinion behind them due to the public consultation process employed during the investigative phase.

Also, the IJC monitors compliance with the terms and conditions set forth in Orders of Approval it has issued. And, when requested by the two governments, it may monitor and coordinate actions or programs that result from governmental acceptance of recommendations made earlier by it.

In implementing the recommendations contained in IJC reports, the two governments, in some cases, have given specific responsibility and authority to the IJC in addition to those it possesses by virtue of the Boundary Waters Treaty. The 1972 Great Lakes Water Quality Agreement is an example of the governments formally conferring additional responsibility on the Commission.

Currently, when the IJC receives new References from the two governments, the assessment of environmental impact has become of paramount consideration; its regulatory function is declining in relative significance. This is apparent in the Great Lakes Water Quality Agreement, as well as in other References – the Poplar, St. Croix, Saint John, Champlain-Richelieu, and Garrison Studies. These are all concerned with the potential degradation of water quality and environmental disruption and point to a shift in the nature of international water management problems.

The technical studies and field work required to carry out these functions are performed by more than two dozen international boards appointed by the IJC, of which there are three types. Boards of Control supervise agreements reached through the IJC on the maintenance of lake levels, flows or the operation of control works which affect water levels and flows at the boundary. Investigatory Boards and Advisory Boards conduct technical investigations or studies of water quality or pollution problems for specific waters, to recommend action or remedial measures. Board members are selected from federal, state, provincial, and occasionally from the private sector, on the basis of professional competence. They bring with them financial and technical support from their agencies, but are expected to perform independently of agency biases.

Since its inception, the IJC has had 107 subjects placed before it by the national governments; except for a few cases, it has reached unanimous decisions and, for the most part, the governments have accepted its recommendations.

The main boards with international responsibilities are listed in Table 12. Although most of those listed are administered by the IJC, certain boards and committees fall outside its jurisdiction. One of these, the Columbia River Treaty Permanent Engineering Board, with two members from each country, reports directly to the two governments and is required to keep the governments advised on matters which will ensure that objectives of the International Columbia River Treaty are met. Amongst others reporting directly to the two governments are the Lake Memphremagog Board, the Great Lakes Fisheries Commission and the Canada-U.S. Committee on Water Quality in the Saint John River.

Apart from specific treaties or agreements between Canada and the United States, a close measure of cooperation exists on an informal basis. To enable the international boards to carry out their investigatory or supervisory responsibilities, Environment Canada operates several international streamflow and water level stations in cooperation with the U.S. Geological Survey. These stations are located at boundary crossing points on the more important international streams.

The Boundary Waters Treaty is a remarkable document, considering it was written some 70 years ago with such foresight and flexibility that it has had to be amended only once, in 1950, when special sections dealing with the Niagara River diversion were replaced with the Niagara River Treaty. In setting out limitations on the freedom with which each country could act, the Boundary Water Treaty provided safeguards on water levels and flows and pioneered restrictions on transboundary pollution long before environment became a major concern; it provided a forum for affected interests to be heard long before public participation became a prerequisite for resource planning; it specified certain rules to govern dispute settlement; finally, its terms were broad enough for boundary problems other than water to be investigated and reported, such as problems of air pollution.

Examples of Canada-U.S. boundary issues, both recent and past, are described in the following.

International Great Lakes Levels Advisory Board

Recognizing the need for public input into the lake level decision-making process, the IJC, in its 1976 report "Further Regulation of the Great Lakes", referred to the need for a panel to provide advice on riparian concerns and other citizen interests concerning the St. Lawrence River and Lake Ontario. To this end, the IJC established the Great Lakes Levels Advisory Board in 1979 and appointed eight persons from each country; half the members are private citizens while the others hold governmental positions with duties connected with levels and flows. All members were appointed for two-year terms. The Board held its first meeting in December 1979.

This Board is responsible for advising the IJC on activities that might have a significant impact on water supplies, levels and flows in the Great Lakes, connecting channels and the St. Lawrence River.

The Board informs and advises the IJC on the effect of programs such as new structures, structural alterations, landfill, shoreline development and dredging for navigation or other purposes, proposed programs of winter ice management for navigation or other purposes, potentially significant weather modification activites, and other activities affecting levels and flows. It also studies and makes recommendations on practical methods of further increasing public awareness of and involvement in all issues relating to Great Lakes supplies, levels and flows.

Ross Dam – Skagit River

The Ross Dam, on the southward flowing Skagit River in Washington State, is located some 32 km downstream from the International Boundary. The dam was built by the City of Seattle between 1937 and 1940 for electric power purposes. The City applied in 1941 for the right to raise the dam by stages to a reservoir level of 525 m and thus flood across the International Boundary and into British Columbia for a distance of 17 km. The IJC issued an Order of Approval in 1942 for the 525 m reservoir operation, subject to the condition that Seattle and British Columbia negotiate a compensation agreement for the land flooded in Canada.

The dam reached an elevation of 472 m in 1947 without transboundary flooding and, by annual agreement with British Columbia, was raised to 488.4 m by 1966, at which time it was flooding about 1.7 km upstream into Canada.

A compensation agreement was signed by the City and British Columbia in 1967 but, soon thereafter, concern developed in Canada that the 1942 Order and the compensation agreement did not take proper account of the potential adverse environmental impacts on the recreational potential of the Canadian section of the valley.

Pursuant to a Canada-United States reference of April 1971, the IJC in its report of December 1971, noted several questions that the U.S. government should consider including the availability of alternative sources of power.

In 1974, British Columbia requested the IJC to reconsider its 1942 Order of Approval, and argued that the water level at the boundary should be limited to its natural level. Although the IJC has authority to review such orders, it was of the opinion that direct discussions between the two parties was the most appropriate means of resolving differences. Consequently, the 1974 request was set aside by the IJC as a negotiated settlement was anticipated. These talks broke down in 1980 and the province repeated its earlier (1974) request to the IJC to reopen the 1942 Order of Approval and to have the 1967 compensation agreement declared null and void. In a supplementary order dated 28 April 1982, the IJC ordered Seattle to maintain the level of the Skagit at the International Boundary at or below elevation 488.4 m for a further year and initiated the establishment of a Special Board directed to achieving and implementing a negotiated mutually acceptable agreement between British Columbia and the City of Seattle.

Pollution Advisory Boards
- St. Croix River Pollution
- Rainy River Pollution
- Red River Pollution
- Air Pollution-Boundary

Investigative-Engineering Boards
- Champlain-Richelieu
- Souris and Red Rivers
- Garrison
- Michigan/Ontario Air Pollution
- Roseau
- Lake Erie Regulation
- Great Lakes Diversions and Consumptive Uses
- Poplar Water Quality
- Great Lakes Levels Advisory Board

Great Lakes Water Quality Agreement Boards
- Great Lakes Water Quality
- Great Lakes Science Advisory
- Land Use Activities
- Working Group on Dredging

Boards of Control
- St. Lawrence River
- Niagara River
- Lake Superior
- St. Croix River
- Rainy Lake
- Lake of the Woods
- Souris River
- St. Mary-Milk Rivers
- Kootenay Lake
- Osoyoos River
- Skagit River
- Champlain

Other International Arrangements
- Columbia River Treaty Permanent Engineering Board
- Lake Memphremagog Board
- Great Lakes Fisheries Commission
- Committee on Water Quality in the Saint John River
- Niagara Treaty

* All of these boards and committees report to the International Joint Commission except for the five headed Other International Arrangements, which report directly to the governments of Canada and the United States.

Mica Dam is one of the three built to regulate flows for improved power generation on the U.S. portion of the Columbia River and for flood control.

Columbia River

Most of the Columbia River basin, some 417 000 km^2, lies south of the Canada-U.S. boundary; the Canadian portion of approximately 63 600 km^2 lies in southeastern British Columbia. International interest in harnessing the tremendous water power potential of the Columbia River commenced in 1944 due to the northwestern United States demand for electric energy and its ability to finance such development.

Joint negotiations began in 1960 leading to the signing of the Columbia River Treaty in 1961. Under the terms of the Treaty, Canada agreed to build three dams in Canada to regulate flows for improved power generation on the U.S. portion of the river and to provide flood control. These included Mica Dam on the northern bend of the Columbia, Duncan Dam just north of Kootenay Lake, and High Arrow Dam at the southern end of the Lower Arrow Lake. In turn, the United States agreed to provide Canada with a share of the additional power generated at U.S. plants as a result of improved regulation, and to pay Canada for flood control benefits. At British Columbia's request, however, Canada's share of the additional power generated at U.S. plants for the first thirty years was sold in advance to utilities in the United States. The three reservoirs were completed in 1973. The 15.5 million acre-feet of storage required under the Treaty has now been provided as well as additional storage to provide optimum at-site generation of electric power at the Mica Dam. Regulation of streamflows has produced flood control benefits in Canada and has enabled construction of two hydroelectric plants in Canada, one on the Kootenay River and the other on the Columbia River.

Flathead River Basin

The Flathead River basin straddles the Montana-British Columbia boundary. In response to the recognition that the basin was undergoing significant development pressures within both the United States and Canada, the U.S. Congress in 1978 authorized a five-year Environmental Impact Study. Two major energy-related development proposals are in the forefront of concerns regarding the future management of basin water resources. Most significant in terms of international implications is the proposed large scale open pit coal mine at Cabin Creek, eight miles north of the Canada-U.S. boundary. Cabin Creek flows into the North Fork Flathead River, which has been designated as a component of the U.S. National Wild, Scenic and Recreational River System. The coal operations could result in increased sediment loads to the Flathead River, acid mine drainage, and leaching of nutrients and complex organics. Moreover, gas and oil exploration in the basin is proceeding in both Canada and the United States and the possibility of medium to large discoveries could lead to air and water quality degradation in the Flathead watershed, adversely impacting upon Glacier National Park and the Flathead National Forest.

Steps have been taken to hold Canada/U.S. bilaterial meetings to exchange data, review the status of development proposals, and establish mechanisms to oversee development in the North Fork Flathead River basin in a manner that will maintain its unique physical, biological and social systems.

St Mary and Milk Rivers

The St Mary and Milk Rivers both have their headwaters in the State of Montana from where they flow northeastward into Canada. After crossing the boundary, the St Mary River retains its northeasterly direction in Canada; on the other hand, the Milk River takes on an easterly direction for nearly three hundred kilometres parallel to the International Boundary. It then turns southward and recrosses the boundary into Montana, just west of the Alberta-Saskatchewan boundary.

The apportionment of the flows of the St Mary and Milk Rivers, with their limited water supply, developed into a major controversy between Canada and the United States, even before the signing of the Boundary Waters Treaty. As a result, when the Treaty was signed, resolution of this controversy was incorporated as Article VI of the Treaty.

The basic principles of Article VI were that the St Mary and Milk Rivers were to be treated as one stream for the purposes of irrigation and power, and that the waters were to be apportioned equally between the two countries; also, Canada was entitled to a prior appropriation on the St Mary and the United States, a prior appropriation on the Milk. The Treaty also made provision for the channel of the Milk River in Canada to be used for conveying U.S. flows diverted from the St Mary River. Measurement and apportionment of the water would be made by accredited officers of Canada and the United States under the direction of the IJC. Representatives of Canada and the United States interpreted Article VI differently and it was necessary for the IJC to resolve this difference before actual division of the water began.

Although the flows delivered across the boundary by both countries may be deficient for some periods during the irrigation season, the deficits are adjusted during subsequent deliveries and each country receives its allotted share.

The construction of a storage project on the Alberta portion of the Milk River is currently under consideration to retain the Canadian share of the spring runoff. The Alberta studies show that if sufficient storage could be provided in Canada, the annual water supply should be adequate to meet present needs, as well as provide additional supplies for new irrigation developments.

Poplar River

The Poplar River basin is situated in the semi-arid region of southern Saskatchewan and northeastern Montana. Its headwaters and one third of the drainage basin are in Canada. Problems related to inadequate water supplies have existed since the area was first settled in the 1880s. The total average annual natural flow of major tributaries at the International Boundary is approximately 42 000 cubic decametres (34 000 ac-ft). Development dependent on water resources is limited because water supplies are insufficient, unreliable and too poor in quality to satisfy many requirements.

Responding to increasing demand for energy in the Province of Saskatchewan, the Saskatchewan Power Corporation (SPC) determined that adequate coal resources exist in the area west of Coronach, Saskatchewan to support a coal-fired, electric power generating plant. The East Poplar River is expected to provide sufficient cooling water for a power plant with two 300 MW units.

On September 4, 1974, the SPC announced plans for the construction of the electric power plant on the East Poplar River near Coronach, Saskatchewan. Concurrently, the Government of Saskatchewan appointed a Board of Inquiry. In its 1975 report, the Board of Inquiry concluded that a 300-megawatt (MW) plant at Coronach was economically desirable. It also recommended that the Saskatchewan Minister of the Environment appoint a further Board of Inquiry to review the final proposals for mitigation of the environmental effects and to receive public comment on the measures. Further, the Board of Inquiry recommended that the Government of Saskatchewan request the Government of Canada to take the steps necessary to achieve an equitable apportionment of the flows of the Poplar River system to enable Saskatchewan to make sound water development plans for this area of the province.

In 1975, the Government of Saskatchewan authorized the SPC to proceed with construction of the dam and power plant, subject to the conditions in the Boundary Waters Treaty being met. Subsequently, the Government of Canada granted the SPC a five-year licence under the International River Improvement Act, again subject to the terms of the Boundary Waters Treaty. Responding to U.S. concerns regarding transboundary implications of the proposed SPC development at Coronach, the IJC instructed its International Souris-Red Rivers Engineering Board to prepare recommendations for the apportionment of the transboundary flows of the entire Poplar River system; the report, completed in 1979, concluded that water apportionment would adversely affect biological resources and lower flushing rates on the river.

Even before the apportionment report became available, the two governments realized the need to undertake a water quality study of the river and to include in the study the transboundary water quality implications of the SPC thermal power plant and ancillary works. They, therefore, issued a new Reference to the IJC in 1977 relating to the water quality of the Poplar River basin and the implications of the SPC generating units. The report of this Reference was delivered to the IJC in 1979 by its International Poplar River Water Quality Board.

The water quality report noted that the proposed development will not present new problems but will aggravate existing ones. Except for boron and total dissolved solids, water quality objectives probably would not be exceeded. A number of alternatives are possible for mitigation of all expected adverse water quality effects of SPC development. The Board cautioned, however, that the information available to it was inadequate in many important aspects. "Future water quantity and quality considerations of boundary waters should be examined simultaneously", the Board said.

Bilateral discussions between Canada and the United States have resulted in both sides agreeing to press forward with the development and implementation of a cooperative monitoring program based on the needs identified in the Poplar Water Quality Board report. The first unit at the Poplar River station was commissioned in June 1981. A Bilateral Monitoring Committee, established in 1981, has begun monitoring water quantity, water quality, air quality, ground water levels and ground water quality in the vicinity of the power station, and a quarterly exchange of information between Canada and the United States has been initiated.

The Garrison Diversion Unit

Construction of the Garrison Diversion Unit was authorized by the U.S. Congress in 1965 for the purpose of irrigating 100 000 ha of farmland, to provide municipal and industrial water supply to 14 communities, and to make provision for recreational, fish and wildlife opportunities in North Dakota using water diverted from the Missouri River. Since many features of the Diversion Unit, as originally proposed, are in the Hudson Bay drainage basin, much of the drainage and wastewaters from the irrigated areas would flow into transboundary streams and could have an adverse impact on Canada.

The governments of Canada and Manitoba expressed concern that the return flows from the diversion would result in the transfer of foreign biota (fish species, parasites and diseases) north of the boundary that would result in serious and irreversible damage to the multi-million dollar Manitoba fishery. This would constitute a violation of the Boundary Waters Treaty.

In October 1975, the IJC was asked by Canada and the United States to examine and report on the transboundary implications of the proposed Garrison Diversion Unit. The International Garrison Diversion Study Board completed this examination in January 1977, and, later the same year, the IJC, in its report to the two governments, agreed that the proposed diversion could result in flooding in the Souris River, water quality degradation in the Souris and Red Rivers and the transfer of foreign biota from the Missouri River into the Hudson Bay drainage basin.

Canada has since reiterated its position that in the absence of agreed technological means to prevent such biota transfer, the Garrison project should be modified to prevent any diversion of water which would ultimately cross the boundary. The United States has officially agreed to meet its obligations under the Boundary Waters Treaty.

The Aux Marais Drainage and Pembilier Dam

The Pembina River rises in south central Manitoba and flows in an easterly direction into North Dakota where it discharges into the Red River, three kilometres south of the International Boundary. Transboundary flooding is the main international issue in the Pembina River basin; to the north, the adjacent Buffalo Lake Drainage and Aux Marais River basins are also affected by high water levels in the Pembina River. An initial study was undertaken by the International Pembina River Engineering Board in the early 1960s, and subsequent studies have been carried out by several joint U.S.-Canada Committees.

In 1967, the IJC proposed a water management plan which involved the construction of two dams – the Pembina Dam in Canada and the Pembilier Dam in North Dakota – to create reservoirs in both Canada and the United States. The proposal was considered worthwhile for flood control but there was some question as to whether the plan was economically viable.

After the floods of the early 1970s, U.S. interests were anxious to proceed with their portion of the plan. Although a U.S. Corps of Engineers' feasibility study, completed in 1976, recommended the construction of a multi-purpose dam and reservoir in North Dakota for flood control, water supply and recreation a re-evaluation in 1982 was less favourable. Although dam construction in Canada was not under consideration, Canada could gain flood control benefits from the Pembilier Dam in North Dakota and was prepared to share in the cost. Farming groups in the Neche area of North Dakota, whose lands drain into Manitoba, have been seeking improved drainage services for their lands. To alleviate these problems in contiguous basins due to poor land drainage, channel improvements were proposed for the Aux Marais River. Manitoba had requested that the Aux Marais project be considered in conjunction with the Pembilier Project, as these projects are interrelated. Conflicts over dyking, flooding and drainage at the boundary could have been reduced if the Pembilier and Aux Marais projects were to proceed.

Roseau River Basin Study

The Roseau River flows in a northwesterly direction from Minnesota to Manitoba and discharges into the Red River 80 km south of Winnipeg. Flooding and associated environmental deterioration downstream in Manitoba as a result of flood control and drainage works in Minnesota have been the transboundary issues on the Roseau River since the original reference to the IJC in 1929.

In 1971 when the second series of Roseau studies was launched under the auspices of the International Roseau River Engineering Board, two questions required answers: (1) Is it practicable and desirable to coordinate projects for the control of Roseau River waters and its tributaries on both sides of the boundary? (2) What would be the impact of proposed United States flood control works on the flows of the Roseau and Red Rivers and, if remedial works are necessary, how should costs be apportioned between the two countries?

In September 1975, the Study Board submitted its final report to the IJC, recommending a coordinated plan for water use and control that would permit each country to understand and anticipate potential impacts of its water resource plans on its neighbour. Also, the Board identified protective measures, and their associated costs ($3.1 million – 1975), required to mitigate increased flood flows in Manitoba due to channelization upstream of the boundary by the U.S. Corps of Engineers. It recommended that these costs be assigned to the United States. Moreover, it recommended that the matter of liability regarding possible damages to Canada between beginning of construction in United States and the completion of Canadian mitigating works be negotiated by the two governments.

An environmental impact study was completed by the U.S. Corps of Engineers by December 1980, and negotiations regarding mitigation works and compensation to Canada will likely begin in 1982.

Great Lakes Water Quality Agreement

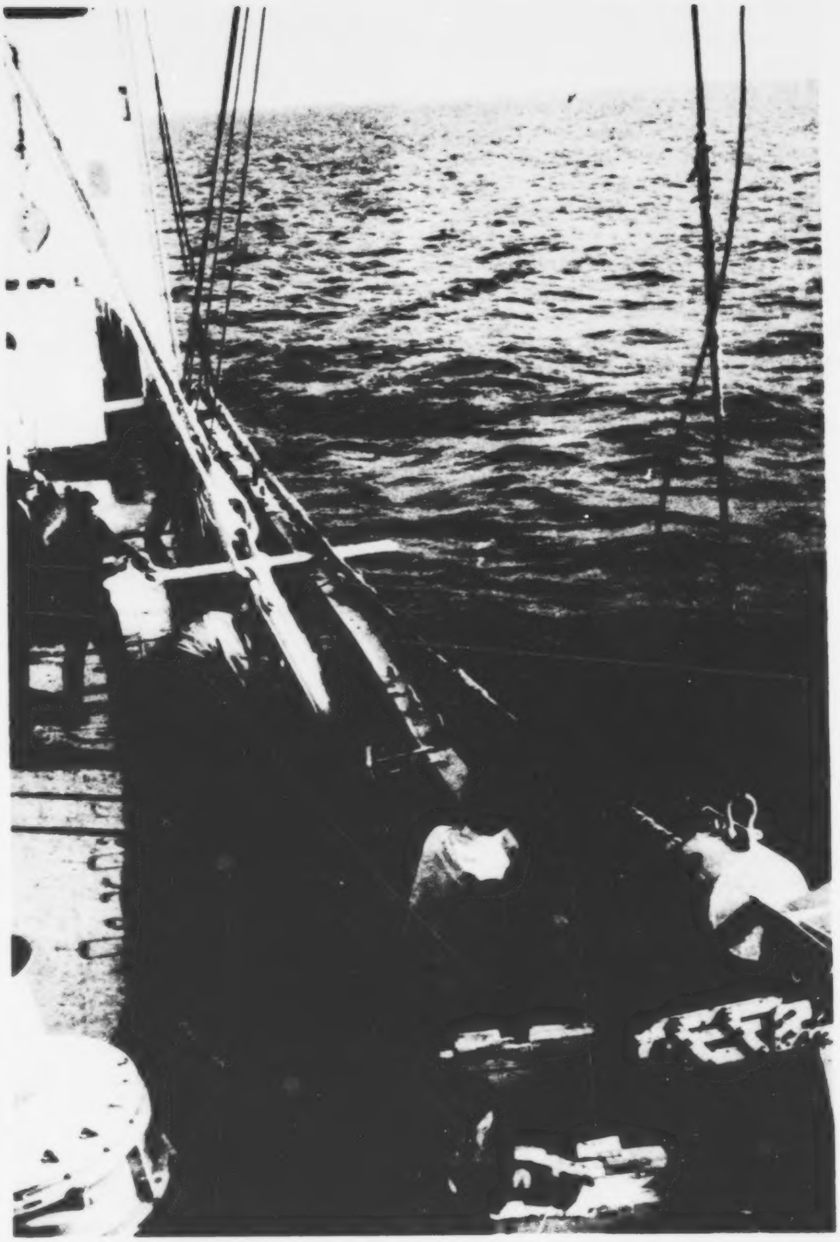
In 1972, Canada and the United States signed a Great Lakes Water Quality Agreement and agreed to undertake measures deemed necessary to restore and enhance the water quality of the Great Lakes System. In 1978, a second agreement was signed to further this work.

The IJC assists the two governments in the implementation of the Agreements. Its role is to collect, analyse and disseminate information concerning the operation and effectiveness of programs and measures undertaken to achieve the goals set, and to report to the various governments on progress made.

Recommendations for measures required to meet the water quality objectives of the Agreement are developed by the Great Lakes Water Quality Board and the Great Lakes Science Advisory Board (formerly the Research Advisory Board).

In 1981, the Water Quality Board noted that after nearly ten years and the expenditure of $6.6 billion, the major goal of phosphorus control from municipal waste treatment facilities in the Great Lakes has largely been achieved. Major problems identified which still must be dealt with to achieve goals of the Agreement include the presence of persistent toxic substances, concentrations of phosphorus and heavy metals, and the disposal of hazardous industrial wastes.

It is becoming apparent that water quality of the Great Lakes cannot be improved significantly unless nonpoint land use sources of pollutants are dealt with along with the more obvious point-source pollution problems. The IJC and its advisors have gone on record as saying that a comprehensive ecosystem approach to water quality management, which considers the interaction of air, water, minerals and living organisms – including man – within the basin, is essential if the waters of the Great Lakes are to be cleaned up. This message in greater detail appears later in this chapter.



One of the measures agreed to in the 1978 Great Lakes Water Quality Agreement was the implementation of a coordinated surveillance and monitoring program in the Great Lakes system.

International Great Lakes Diversions and Consumptive Uses Study

The International Great Lakes Diversions and Consumptive Uses Study Board was established in 1977 to undertake a study of the diversions and consumptive uses in the Great Lakes basin and their effects on water levels and flows in the Great Lakes. Previous investigations had not examined the effects of consumptive uses nor had they considered the impacts or benefits which might be derived from possible alternative methods of managing the basin's diversions. A summary of the consumptive uses portion of the study appears earlier in this Year Book.

The diversions considered in the study are man-made alterations to the water supplies flowing into, within or out of the Great Lakes basin and include the Long Lake/Ogoki Diversions into Lake Superior, the Lake Michigan Diversion at Chicago, and the Welland Canal Diversion out of Lake Erie.

The Study Board identified a number of diversion mangement scenarios and outlined the range of likely impacts on the major interests affected in the Great Lakes basin – shore property, navigation and power. Projections of consumptive uses on the Great Lakes to the year 2035, and the attendant impact on these major interests, also were studied.

The Board developed a public information program to keep the basin public informed of its work and held a set of workshops to receive feedback on its preliminary findings. In its final report to the IJC in 1981, the Board arrived at the following conclusions:

a) the diversion rates into, within and out of the basin cannot be altered to reduce extreme high levels on the Great Lakes without causing an overall long-term net economic loss;
b) the diversion rates into, within and out of the basin cannot feasibly be altered to increase extreme low levels on the Great Lakes during periods of low supply;
c) periodically, all diversons (regardless of size) should be monitored and their accumulated effects estimated, evaluated and reported upon so that appropriate public policies can be developed; and,
d) consumptive uses should be monitored periodically and their impacts (along with various control strategies) studied so that appropriate public policies can be developed to minimize long-term adverse effects.

International Lake Erie Regulation Study

In February 1977, the governments of Canada and the United States requested the IJC to determine whether limited regulation of Lake Erie water levels would be in the public interest. The request came as a result of the IJC's recommendations to the governments in its 1976 report "Further Regulation of the Great Lakes" and was given added impetus by the record high water levels on Lakes Erie, Michigan and Huron, which were causing extensive flood and erosion damages to shoreline properties on the lakes in the early 1970s. The IJC established the International Lake Erie Regulation Study Board to perform the investigations.

Limited regulation of Lake Erie would involve increasing its outflows during periods of above average water supplies to the upper Great Lakes from which Lake Erie receives over 80% of its water. This would require regulatory works. The effects of Lake Erie regulation plans on the water levels and outflows of the Great Lakes-St.Lawrence River system were evaluated in detail. In addition, the economic impacts of regulation on the major users of the Great Lakes, which include shore property, hydroelectric power, navigation, and recreational beaches and boating interests were estimated. The evaluation of environmental impacts was basically qualitative, and relied heavily on existing data.

The Board conducted a series of public meetings to present the preliminary findings and to obtain the views and comments of the public before preparing the final report in 1981.

Overall, it was determined that the economic losses to users and the cost of the Niagara regulatory works would each exceed any benefits derived from limited regulation of Lake Erie, and no assumptions or techniques could change this.

In its final report to the IJC, the Board concluded:

1. regulation of Lake Erie was not economically justified;
2. a public information program should be encouraged by the Commission; and
3. shore property management practices should be encouraged as a means of reducing flood and erosion damages along the Great Lakes shoreline.

The Board's recommendations are presently being reviewed by the IJC.

Richelieu River – Lake Champlain

Lake Champlain is located mainly in the States of Vermont and New York. Its outlet is the Richelieu River in Quebec which flows north for 128 km to the St. Lawrence River at Sorel. Flooding over the years has caused considerable damage and hardship both in Canada and the United States.

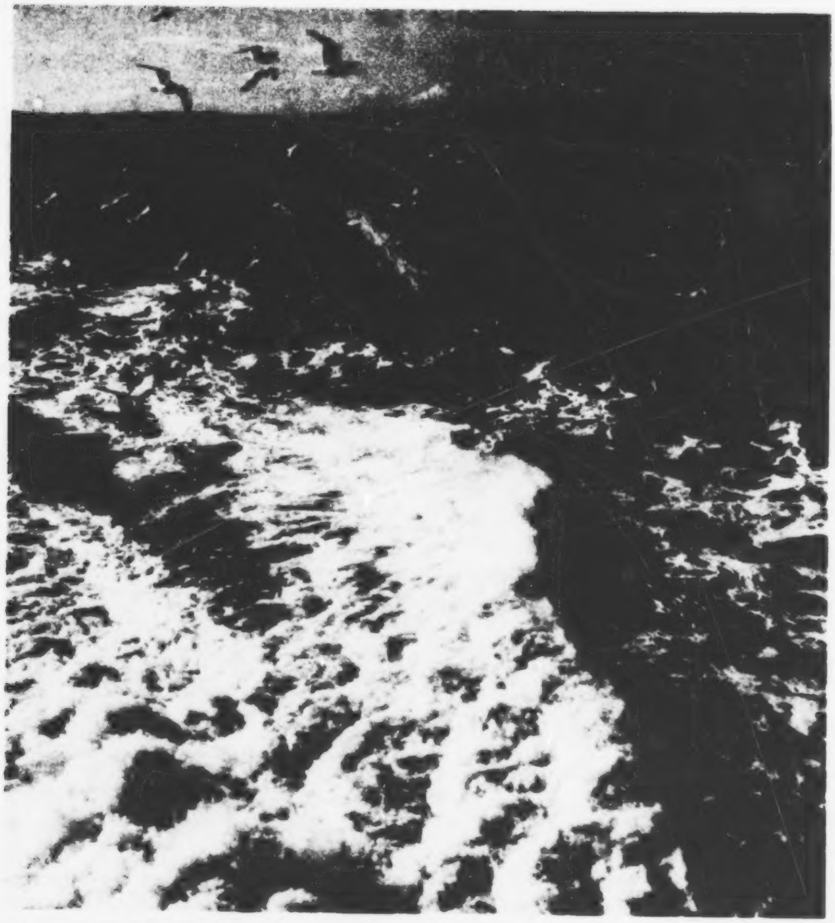
Lake Champlain and the Richelieu River support a great diversity of insect and plant life, fish, fur-bearing animals and waterfowl. The shallows of the lake and the adjoining wetlands are important to the lake's biotic diversity, thus low water conditions too can have serious impacts.

Over the years there have been numerous studies and reports attempting to deal with problems in the basin. In the latest, initiated in 1975, the IJC formed the International Champlain-Richelieu Board to study the environmental, physical and economic effects on both countries of regulating outflows from the lake. The Board submitted its final report to the IJC in 1979 after considerable study, and after conducting several sets of public hearings in both Canada and the United States. In February 1981, the IJC presented its report to governments. It concurred with the basic findings of the Board that flood control by structural means is feasible and economically justified but, because of environmental concerns in the United States, it could not reach a decision as to the desirability of flood control works.

A related issue was the widening of Chambly Canal in 1972-73, which reduced the Richelieu River's cross-section, and contributed to the increase in water levels on Lake Champlain. While this increase is small (about 10-12 cm) compared to the flooding by natural events, mitigation measures are under consideration in Canada.

Saint John River Basin

The Saint John River has its headwaters in the United States but, after forming a section of the boundary between Maine and



Lake Champlain and the Richelieu River support a great diversity of insects and plant life, fish, fur bearing animals and waterfowl.

New Brunswick, flows entirely in New Brunswick on its path to the ocean. As approximately 14% of the basin lies in Quebec, 35% in Maine and 51% in New Brunswick, intergovernmental cooperation in managing the water resource in the basin is essential.

The uses made of the waters of the Saint John River have long been in conflict and, in the process, the water has deteriorated in quality to the point where the effective range of uses has become limited.

The Canada-United States Committee on Water Quality in the Saint John River was established by Canada and the United States in 1972 to review progress in the conduct of water quality planning, to exchange information, to assist in coordination and consultation, and to make appropriate recommendations regarding improvement of water quality in the basin. Coincident with the Committee's creation, the IJC was requested to recommend action in regard to matters examined by the Committee and to advise on further institutional arrangements. The Committee's report was presented to the IJC in September 1975 and the IJC's final report to governments was completed in September 1977. Subequent to that date, the Committee's operations have continued and focussed on a further review and revision of water quality objectives recommended in its 1975 Report. In the summer of 1981 the revised objectives were submitted for adoption by governments. Currently, they are undergoing review.

Seventeen individual parameters and a list of pesticides were selected for inclusion in the revised objectives. The selection was made on the basis that objectives should be restricted to parameters whose levels might be influenced by the existing or predicted patterns of settlement and land use and whose levels were amenable to local control. Objectives were developed only for contact recreation and the preservation of fish and other aquatic life. Development of the water quality objectives took the nature of existing monitoring programs into account.

In 1965, a hydroelectric project in the upper Saint John River in Maine, referred to as the Dickey-Lincoln School project, was authorized by Congress to provide additional power to meet projected requirements for the New England States. The impact on Canada would be the flooding of areas in the Quebec portion of the basin, as well as possible impairment of water quality and fisheries downstream of the regulating dam. An environmental impact statement addressing U.S. concerns was conducted by the U.S. Corps of Engineers in 1981. Since then, a study of the physical and biological effects in Canada was also conducted. A recent proposal points to the United states considering only the Lincoln School portion of the project. To date, the United States has not made a firm proposal to Canada.

St. Croix River

The St. Croix River forms the boundary between Maine and New Brunswick in a short section adjacent to the Bay of Fundy. An IJC report to the governments of Canada and the United States in 1959 emphasized the need for improving water quality in the river. On September 30, 1961, the governments formally agreed that pollution abatement measures would be undertaken.

In 1962, when the IJC established its Advisory Board on Pollution Control for the St. Croix River, untreated domestic sewage was being discharged to the river from municipal systems in both Maine and New Brunswick. Industrial pollution was also contributing to the degradation of the river. Pollution abatement programs for treating industrial and municipal waste discharges to the St. Croix River system were established by the mid-1960s.

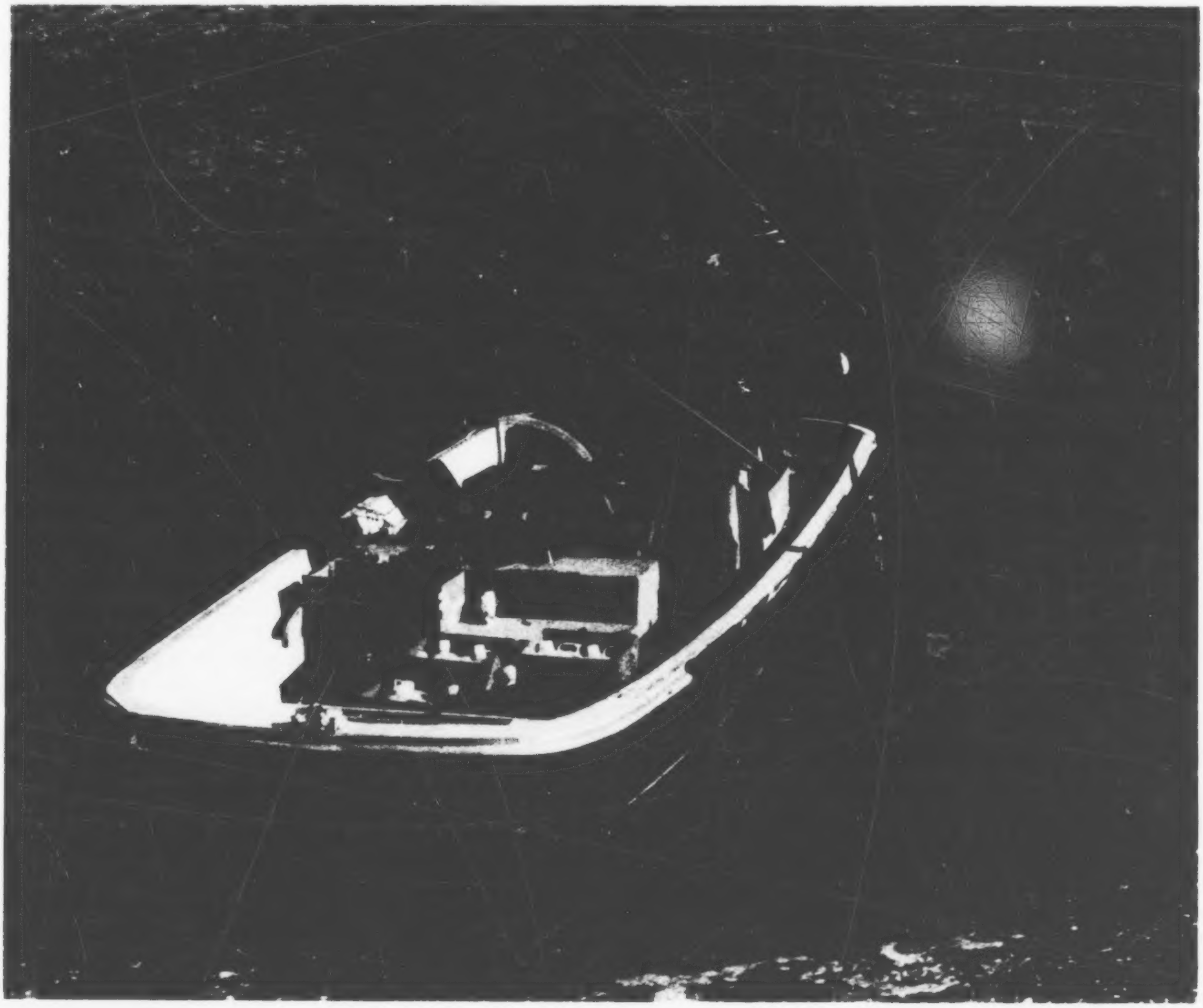
In its 1977 report to the IJC, the Advisory Board reported a dramatic improvement in water quality to the extent that the migration of anadromous fish, particularly the Atlantic salmon, was once again possible. This has prompted a recommendation pertaining to the rehabilitation of the salmon fishery. Meanwhile, monitoring of the water quality is continuing.

For water resources to be used to their fullest, the quality of the water must be safeguarded commensurate with current or foreseeable uses. An earlier section of this Year Book reports on the various uses of water. This section covers water quality monitoring in terms of the pollution cleanup in the Great Lakes basin, and the need for setting water quality objectives for transboundary rivers.

Lakes and rivers across Canada differ greatly in their characteristics. No two lakes are alike. Even rivers will differ depending on their relative size, flow characteristics, the hardness of their waters,and the types of aquatic organisms which inhabit them. Thus, each water quality problem to be addressed is unique.

During water quality monitoring, data on physical, chemical and biological aspects are collected and analyzed for a variety of purposes, including the monitoring of the water quality of rivers below waste outfalls or where they cross provincial or international boundaries. In a remote area in which an industrial complex is to be built at some future time, monitoring provides a thorough assessment of the waters' quality in advance of development to set the scene for a water quality management program that will establish the water quality objectives for that area and ensure that the objectives are maintained. The information gained can be used both to measure against the actual effects of the new complex as it comes on line and to estimate the overall effects that the complex will have if allowed to go unchecked.

In some rivers and lakes, special monitoring programs are designed to investigate particular problems, for example, the eutrophication of a lake from extensive nutrient input. A much broader program, to conduct a cleanup of the pollutants in the Great Lakes basin under the auspices of the International Joint Commission, is already in place. The progress of that program is discussed in the section which follows.



During water quality monitoring, data on physical and biological aspects are collected and analyzed for a variety of purposes.

Cleansing the Waters of the Great Lakes

A Brief History

The signing of the Canada-United States Great Lakes Water Quality Agreement in 1972 and the subsequent revisions to that agreement in 1978 may suggest that water quality problems in the Great Lakes are of relatively recent vintage, but such is far from the truth.

As early as 1912, the International Joint Commission was requested to determine the extent of pollution in boundary waters from Rainy River in northwestern Ontario to the St. John's River in New Brunswick. After six years of study, the IJC reported, amongst other things, that interconnecting channels of the Great Lakes as well as the international section of the St. Lawrence River were polluted. Similarly, the Detroit and Niagara Rivers were singled out as possibly endangering the health and welfare of the citizens of both countries. In its recommendations, the IJC requested authority to make regulations and oversee the cleanup. Although the recommendations were received favourably by both governments, they were never acted upon, possibly because they were too far ahead of their time.

In the years following the second world war, the IJC was again asked to determine whether a transboundary pollution condition existed in the connecting channels of the Great Lakes system. On completion of its study in 1950, the IJC reported that the waters were badly polluted, primarily by industrial and municipal wastes. It recommended adoption of a set of objectives which included minimum criteria for water quality suitable for all normal uses. It also recommended that it be allowed to establish control boards to monitor the pollution problem and cleanup action and make progress reports to the governments. In 1951, the governments adopted these recommendations and two advisory boards were set up; one for the St. Clair, Detroit and St. Mary's Rivers and the other for the Niagara River. Federal, state and provincial officials served on these boards to oversee the cleanup action undertaken by the municipalities and industries in the areas affected. However, progress was slow and acceptance of the recommendation by governments was not followed through with effective action.

During this period, the problem of multiple jurisdictions became apparent. The interconnecting channels could only be tackled by a concerted and coordinated effort of the federal, state and provincial governments, as well as local jurisdictions. This point was clearly stated in the next reference given to the IJC by the governments in 1964, in which the Commission was directed to investigate the seriously polluted condition of the Lower Great Lakes – Lake Erie and Ontario – and the international section of the St. Lawrence River, and to make recommendations.

There followed a number of years of study of the pollution of Lakes Erie and Ontario coordinated by the IJC, and subsequent research on Lake Erie eutrophication was conducted by Canada Centre for Inland Waters' scientists in collaboration with Environmental Protection Agency (U.S.) staff.

A final report was made by the IJC in 1970. Not only did it find that Lakes Erie and Ontario were seriously polluted, but it noted that the situation was worsening, and recommended a number of far reaching remedial measures.

Concerned over the state to which this problem was reaching, the Government of Canada, in 1970, invited representatives from the United States to join in discussions aimed at cooperative action to restore and protect Great Lakes water quality and to implement recommendations of the IJC. This led to a Canada-United States ministerial meeting on Great Lakes pollution in Ottawa in June 1970.

While the first ministerial meeting did not provide the mechanism to tackle the problem, it nevertheless resulted in the establishment of a joint Working Group to review the IJC recommendations and to report back to a second ministerial meeting. Over ensuing months, the Working Group showed itself to be in favour of an agreement on Great Lakes water quality along the lines proposed by Canada and both sides reached a consensus on the elements which should be incorporated into such an agreement. At a ministerial meeting in Washington, in June 1971, both countries consented to enter into a formal international agreement. This subsequently led to the signing of the Canada-United States Agreement on Great Lakes Water Quality on April 15, 1972, thereby establishing a set of principles which would guide the preservation and enhancement of the Great Lakes.

The intent behind the 1972 Agreement for the Great Lakes System was, in effect, that the waters should be free from various substances entering the waters as a result of human activity to a degree that is unsightly or deleterious, creates a nuisance, or adversely affects human, animal or aquatic life. Specific water quality objectives for the boundary waters of the Great Lakes System included objectives for microbial contamination, dissolved oxygen, total dissolved solids, taste and odour, pH, iron, radioactivity and phosphorus. The 1972 Agreement also included interim objectives calling for restrictions on temperature; mercury and other toxic heavy metals; persistent organic contaminants toxic or harmful to human, animal or aquatic biota; settleable and suspended materials; and oil, petrochemicals and non-mixing substances.

To achieve these objectives, the Agreement also called for the implementation of a number of comprehensive pollution control programs. These included the abatement and control of municipal sewage and industrial discharges into the Great Lakes; the control of inputs of phosphorus and other nutrients; the abatement and control of pollution from agricultural, forestry and other land use activities, shipping sources, dredging activities, and onshore and offshore facilities; and the maintenance of a joint contingency plan for use in the event of the discharge, or threat of discharge, of oil or other hazardous polluting substances.

While the Great Lakes Water Quality Agreement was being negotiated between Canada and the United States, it became readily apparent that major gaps in knowledge existed with respect to the nature and extent of pollution problems in the lakes. For this reason, two new References to the International Joint Commission were incorporated into the 1972 Agreement. These were as follows:

Upper Great Lakes Reference: to identify existing water quality problems within the Upper Great Lakes (Superior and Huron); and to recommend a program which would prevent further deterioration of these lakes.

Pollution from Land Use Reference: to identify the nature and magnitude of Great Lakes pollution resulting from land based activities including agriculture, forestry, urban and industrial land development, utility and transportation systems and natural sources; and to recommend a practical program of remedial actions.

During 1977-78, the Governments undertook a detailed review of the successes and failures which resulted from implementing the 1972 Agreement. During this exercise, a number of increasingly significant problems were considered including toxic substances in fish and wildlife, the extent of land drainage pollution, and the influence of air pollution on water quality. The United States and Canada subsequently negotiated a second Agreement which they signed in 1978.

Although the 1978 Agreement reaffirmed the determination to restore and enhance water quality in the Great Lakes system, it is more comprehensive than the 1972 Agreement. The experience gained under the 1972 Agreement has given the governments a firmer basis upon which to develop new and more effective actions to restore and enhance water quality in the Great Lakes basin.

The Specific Objectives of the 1972 Agreement have been revised and expanded, and now number over forty in the 1978 Agreement. These objectives are based on available information on cause effect relationships between pollutants and the ecosystem and on the principle of protecting the most sensitive beneficial use in the boundary waters.

The latest Agreement also incorporates new measures designed to deal specifically with a number of serious basin-wide problems. A commitment is made on the part of the governments to virtually eliminate the discharge of persistent toxic substances into the Great Lakes system, to prohibit the discharge of toxic substances in toxic amounts, and to establish an early warning system to anticipate and prevent future problems associated with toxic substances. Provisions are also included for programs to identify the sources and to assess the effects upon water quality in the Great Lakes system of airborne pollutants, and for the governments to consult on appropriate remedial programs. The Agreement also calls for a coordinated surveillance and monitoring program for the Great Lakes system.

Administrative Framework

Canada and the United States: Owing to the large number of jurisdictions in the basin, numerous federal, provincial and state agencies are involved in the implementation of the 1978 Great Lakes Water Quality Agreement. On the Canadian side, the federal Department of the Environment and the Ontario Ministry of the Environment are the lead agencies with assistance from federal Public Works, Transport and Agriculture, the Ontario Ministry of Natural Resources and the Quebec Environmental Protection Service. The main federal agencies participating on the U.S. side are the Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Coast Guard, National Oceanic and Atmospheric Administration and the U.S. Department of Agriculture. Each of the state agencies having responsibility for environmental management also participate in the program.

While overall responsibility for implementing the 1978 Great Lakes Water Quality Agreement resides with the federal governments of Canada and the United States of America, the nature of many of the commitments contained therein require complementary endorsements on behalf of provincial and state governments in both countries. In Canada, this requirement became readily apparent during negotiation of the 1972 Agreement on Great Lakes Water Quality. To respond to this need, Canada and Ontario signed a federal/provincial agreement in 1971 for purposes of reaching a concensus on Canadian water quality objectives and accelerating investment in both sewage treatment facilities and research into treatment technology. This agreement, known as the Canada-Ontario Agreement Respecting Great Lakes Water Quality, was subsequently revised in 1976 and is presently undergoing a second revision to more accurately reflect changing program requirements and responsibilities of both levels of government. No similar special federal-state agreement was developed in the United States which chose to use existing federal-state mechanisms and programs.

International Joint Commission: Under the first Great Lakes Water Quality Agreement signed in 1972, the International Joint Commission was assigned specific powers, responsibilities and functions. The governments later expanded the IJC's role when they signed the 1978 Agreement. While continuing its function of reporting to the governments about the condition of the Great Lakes, the IJC now also provides advice and makes recommendations to the governments about other aspects of the Agreement, provides assistance in coordinating joint activities envisioned in the Agreement and investigates other Great Lakes water quality concerns at the request of the governments.

Two major boards – The Water Quality Board and the Science Advisory Board - assist the IJC in meeting its Agreement responsibilities. The boards have committees and task forces involving hundreds of people who help them gather data and prepare their reports to the IJC.

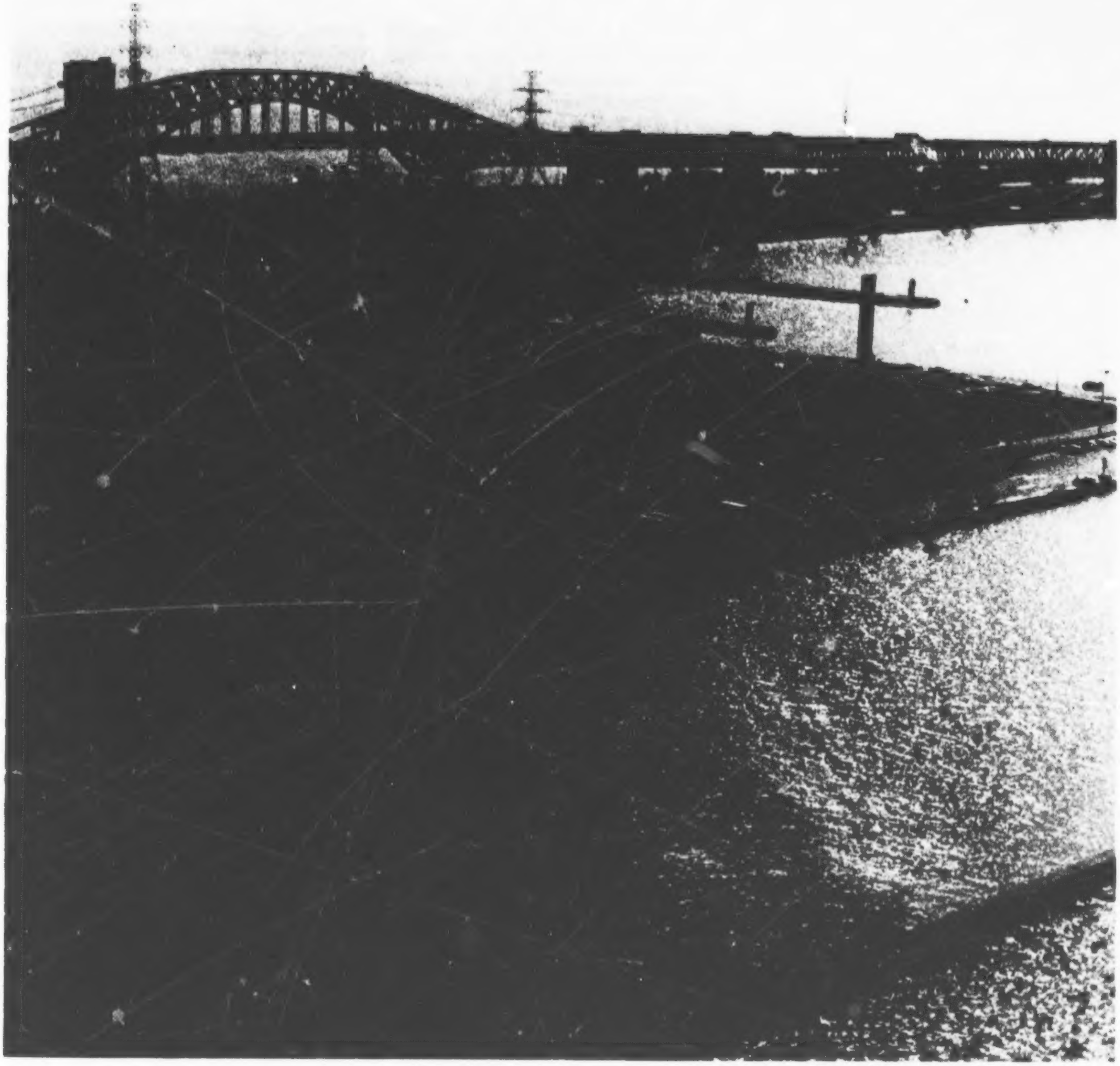
Members of the Water Quality Board are key managers of pollution control programs in government agencies. This group is responsible for collecting data and identifying problems and trends. In its capacity as principal advisor to the IJC, it reports on all the activities under the Agreement except research.

The Science Advisory Board consists of representatives from government agencies, industry and the public. It reviews scientific research and knowledge and uses this information to evaluate current problems and predict future ones. As the scientific advisor to the IJC, the Science Advisory Board develops recommendations on all matters pertaining to research and the development of scientific knowledge pertinent to identifying, evaluating, and resolving current and anticipated problems relating to Great Lakes water quality.

The Great Lakes Regional Office of the IJC in Windsor, Ontario, was established to assist the boards and their sub-groups. The staff also provides Agreement information services.

Status of Pollution Control Programs

Eutrophication and Phosphorus Control: The control of excessive inputs of phosphorus has been recognized since the 1960s as the most important factor in combatting eutrophication and its associated problems in the Great Lakes. For this reason, phosphorus was a major focus of the 1972 Great Lakes Water Quality Assessment under which a number of programs were undertaken in both countries to re-



Since its establishment in 1966, the Canada Centre for Inland Waters has furnished much of the technical input needed for formulation of Canada's water policies and programs in the Great Lakes system.

duce the substantial phosphorus loads to the lakes from municipal wastewater treatment plants in the basin, as well as to reduce the phosphate content of detergents

Detergent Phosphorus Limitations: Limitations on the phosphorus content of laundry detergents have contributed to reductions in phosphorus loadings to each of the Great Lakes. Canada has established a federal limit and five of the eight states bordering the Great Lakes also have limits, as does the City of Chicago, thereby including most of the Illinois portion of the Great Lakes basin also.

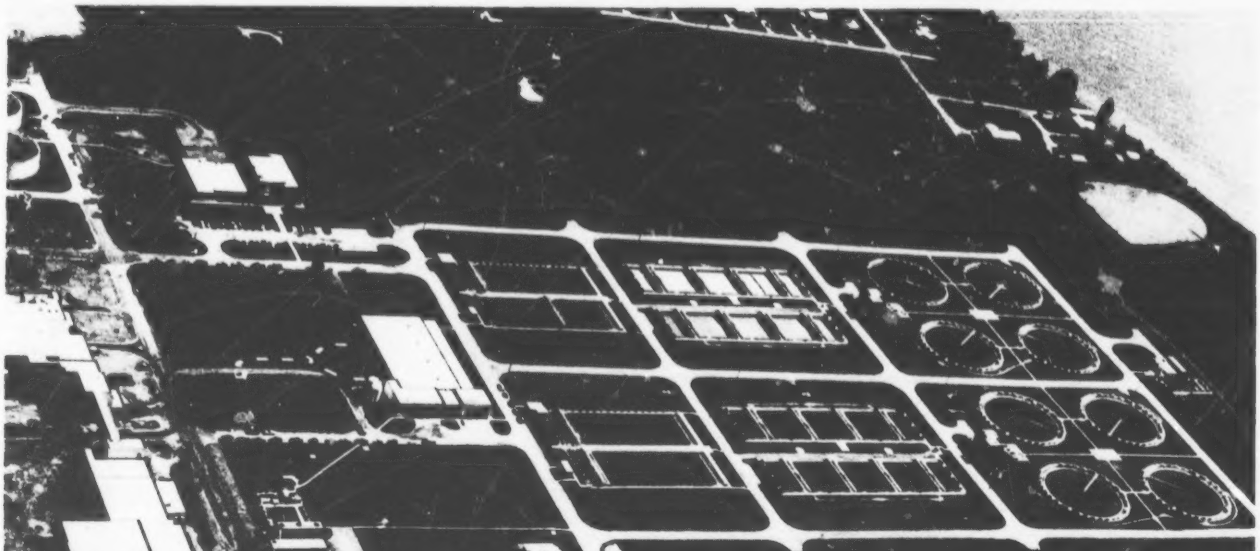
Those jurisdictions in the basin with a detergent phosphorus limitation have reported substantial reductions in influent phosphorus concentrations to municipal treatment plants, and have attributed these to the detergent phosphorus limitation. Lower influent concentrations not only reduce the amount of phosphorus to be removed at municipal wastewater treatment plants but also reduce associated sludge production. A number of municipal wastewater treatment plants currently not meeting their effluent requirements and not expected to do so in the immediate future are located in those jurisdictions which do not have a detergent phosphorus limitation. The IJC has recommended that detergent phosphorus limitations be extended to those jurisdictions that do not have one.

Phosphorus Removal at Municipal Treatment Plants: Even before the total phosphorus loading to the Great Lakes was known, it was evident that municipal wastewater facilities were discharging significant amounts of phosphorus, especially to Lakes Erie and Ontario. A principal requirement of the 1972 Agreement with respect to eutrophication was the implementation of programs to control point-source inputs of phosphorus to these lakes. Since that time, substantial progress has been made. In 1979, facilities were adequate for 84% of the sewered population in the United States basin and for 99% of the sewered population in the Canadian portion of the basin, compared to 5% and 80% respectively in 1971. Since 1972, Canada and the United States have spent or committed more than $6.6 billion for municipal wastewater treatment facilities in the Great Lakes basin. The 1978 Agreement calls for construction and operation of waste treatment facilities in all sewered municipalities to be completed by December 31, 1982.

Toxic Substances: A unique characteristic of the Great Lakes basin ecosystem is the long retention time of the lake waters. The Great Lakes constitute an essentially closed system, entirely unlike riverine systems which discharge their waters and pollutants to oceans in a relatively short time. Due to their closed-system nature, the lakes accumulate persistent toxic substances.

In recent years, the contaminated state of the Great Lakes has been kept under observation. While declines in the concentrations of some toxic chemicals in the sediment and biota have occurred in most lakes, the general level of contamination remains constant because, as analytical capability improves , new contaminants are identified. Clearly, the lakes suffer from widespread contamination and continue to be a major sink for toxic substances. The Great Lakes are a multiple-use resource for the residents of the basin. As such, the surrounding population is exposed to toxic substances from this source through a variety of pathways. Because the full impact of this contamination on human and environmental health is still not well understood,

Since 1972 Canada and the United States have spent or committed more than $6.6 billion for municipal wastewater treatment and distribution facilities in the Great Lakes basin.



this issue is of major concern.

Beginning in the early 1970s, a start was made on the development of procedures and guidelines for identification and control of persistent toxic chemicals such as PCBs and certain pesticides. But it wasn't until 1977 with the passing of the Environmental Contaminants Act in Canada and the Clean Water Act in the United States that a concerted effort was made to tackle toxics and hazardous materials in the Great Lakes.

Under the provisions of the 1978 Great Lakes Water Quality Agreement, the governments of Canada and the United States are now required to control and prevent the input of toxic substances into the Great Lakes, and to rehabilitate portions of the Great Lakes already degraded by toxic contamination. These goals are to be accomplished through the development of programs and activities designed to virtually eliminate the entry of toxic substances into the Great Lakes ecosystem.

The Agreement calls for programs which include inventories of toxic substances ranging from production and use to release or disposal; close coordination between air, water, and solid waste control programs; and joint programs to manage hazardous materials. In addition, the Agreement requires monitoring and research programs to address the increasing threat of toxic substances, and activities in support of an early warning system to anticipate toxic substances problems.

In 1980 the Great Lakes Water Quality Board established the Toxic Substances Committee for the purpose of evaluating programs and activities responding to the Agreement. The underlying problem identified as a result of this evaluation is the absence of an overall Great Lakes management strategy for toxic substances control activities that are being carried out under the various pieces of legislation among the jurisdictions. This fragmentation has resulted in duplicative activities in some cases, incomplete program coverage in others, and a limited management capacity to effectively address emerging complex problems.

The need for better coordination has been recognized, and steps are being initiated to correct this situation. A Toxic Chemicals Management Centre has been established at the national level within Environment Canada, and a Hazardous Contaminants Office has been established in Ontario. In the United States, this coordination is being instituted at the national level through an Interagency Testing Committee and a Toxic Substances Priority Committee. Also, at the national level, the United States Environmental Protection Agency (U.S. EPA) is developing a toxic substances integration strategy to improve coordination among the various laws and programs. While this effort is being undertaken, U.S. EPA regional offices as well as many of the states have developed internal coordination mechanisms to improve integration. These programs are only now in their initial stages of development but, when fully implemented, should enhance significantly the collective capability of the governments in the Great Lakes basin to meet the provisions of the 1978 Great Lakes Water Quality Agreement.

Pollution From Land Use Activities: Past studies have demonstrated that pollution levels in the Great Lakes system could not be attributed entirely to loadings from readily identifiable point sources such as sewer outfalls. Land drainage sources have been shown to be not only significant but also extremely variable and therefore difficult to measure. Subsequent improvements in wastewater treatment for point sources of pollution magnified the relative importance of the land drainage sources of many pollutants, necessitating a clearer definition of the impact of land use activities, practices and programs on water quality in the Great Lakes. For this reason, the governments of Canada and the United States, on signing the 1972 Great Lakes Water Quality Agreement, requested the IJC to investigate pollution of the Great Lakes system from agriculture, forestry and other land use activities.

The study which followed considered diffuse (i.e. nonpoint) sources of pollutants including surface runoff from all land uses and ground water inflows from the entire Great Lakes basin. The atmospheric loading also was evaluated to determine its magnitude relative to the total pollutant load to the Great Lakes.

Of major importance in the conduct of the study, an assessment of the current state of the art was carried out, an inventory of major and specialized land uses and land use practices was conducted, and the degree of impairment to water quality from land use sources of pollution was assessed. An extensive public participation program also was undertaken.

The study demonstrated that phosphorus loads from land drainage and atmospheric deposition contribute to both offshore and nearshore water quality problems. Depending on the magnitude of the point source loads, it was estimated that the combined land drainage and atmospheric inputs to individual Great Lakes in 1976 ranged from 30% (Lake Ontario) to 90% (Lake Superior) of the total phosphorus loading. These proportions should be even higher now because, in some instances municipal phosphate loads have been reduced since 1976.

Toxic substances such as PCBs have been found to gain access to the Great Lakes systems from diffuse sources, especially from atmospheric deposition. Residues of previously used organochlorine pesticides, for example, DDT, are still entering the boundary waters through land drainage in substantial quantities, although in significantly declining amounts, as shown by declining levels in fish tissues. Mercury has been detected in fish tissues in all the lakes. A continuous buildup of lead in the sediments of the Great Lakes has also been noted. In light of the potential for the methylation of lead, this poses a potential problem of unknown dimensions. Lead enters the Great Lakes system in substantial quantities through atmospheric deposition. It is believed that mercury enters the system in a similar manner, although this has not been verified.

Sediment affects the Great Lakes system primarily as a carrier of phosphorus and other pollutants, contributing to the overall pollution of the lakes. Sediment affects nearshore areas through siltation of fish habitat, drainage channels, harbours and bays, thereby necessitating expensive dredging.

Microorganisms enter the Great Lakes system from diffuse sources, resulting in localized problems affecting some nearshore waters. While in many cases it is difficult to attribute pollution (i.e. violation of a specific existing or proposed water quality objective) to any particular land use, it is important to note that it is the cumulative effect of a variety of land use activities that ultimately contributes to pollution of the Great Lakes.

The Martin Karlsen was one of many motor vessels engaged in the monitoring and surveillance of the Great Lakes

The study also revealed that the lakes most affected by phosphorus and toxic substances are Erie and Ontario. Local problems associated with phosphorus, microorganisms and sediment are seen in such areas as Green Bay, Saginaw Bay, southern Georgian Bay, Lake St. Clair, the Bay of Quinte, and the south shore or red clay area of Lake Superior.

Intensive agricultural operations have been identified as the major diffuse source of phosphorus. Erosion from crop production on fine-textured soils and from urbanizing areas, where large-scale land developments have removed natural ground cover, were found to be the main sources of sediment. Urban runoff and atmospheric deposition were identified as the major contributors of toxic substances from nonpoint sources.

In tackling those pollutants, it has been concluded that the remedy of nonpoint source pollution will not be simply nor inexpensively accomplished. Nonpoint sources of water pollution are characterized by their wide variety and large numbers, the seemingly insignificant nature of their individual contributions, the damaging effect of their cumulative impact, the intermittent nature of their inputs, the complex set of natural processes acting to modify them and the variety of social and economic interactions which affect them. The findings of the study do not favour across-the-board measures for nonpoint source pollution control, but rather methodology whereby problem areas are defined on a priority basis to which the most practicable control means for a particular source are then applied.

Both Canada and the United States have implemented a wide range of regulatory and voluntary programs and practices specifically aimed at pest control products; pollution from animal husbandry; the hauling and disposal of liquid and solid wastes; road salting and salt storage; control of soil losses from urban, suburban, and rural areas; and improvements in land use planning and management.

Surveillance and Monitoring: After the 1964 Reference studies on the Lower Great Lakes, the IJC recommended to the governments of both Canada and United States that short-term studies be conducted to assess the sources and nature of pollutants, along with longer-term research and monitoring programs to ensure the best solutions. The 1969 report of several advisory boards to the IJC specifically recommended that adequate water quality surveillance and monitoring activities be maintained in the referenced waters (including inputs from tributaries) to allow for the assessment of and adjustment to programs on enforcement, management, planning and research. Fulfillment of this recommendation occurred in 1978 when one of the measures agreed to in the 1978 Agreement was the development and implementation of a coordinated surveillance and monitoring program in the Great Lakes system.

The program adopted is basically a strategy to assess water quality in the Great Lakes in a comprehensive, coordinated and cost-effective manner. Its objectives are associated with compliance with pollution control requirements, achievement of objectives, evaluation of water quality trends and identification of emerging problems. In addition to these general objectives, one of the major underlying concepts is to prevent the deterioration of water whose quality is currently acceptable.

The program is not intended to be a rigid requirement for performance. Instead, it has been made flexible in order to respond to new issues or changing priorities. It is characterized by an effective flow of information among the several different agencies that conduct it and represents a balanced approach to meet the specific information needs of remedial program managers. Its output is a systematic overview of water quality in the Great Lakes aquatic ecosystem.

One of the fundamental functions of the surveillance program is to obtain information on water quality in order to evaluate the need for new programs and effectiveness of the existing programs. The following are examples of positive actions already taken.

In earlier years, before the program was developed, measurements of the phosphorus content of the lakes and the dissolved oxygen levels in Lake Erie formed the basis for determining that phosphorus control was needed, and resulted in the implementation of basin-wide phosphorus control programs. More recently, continuing measurement of phosphorus has documented improvements in Lakes Ontario and Erie and more localized areas in other lakes. For example, surveillance programs in the Bay of Quinte documented algal and oxygen level responses to phosphorus loading requirements. However, these same studies indicated further phosphorus loading reductions were needed to meet water quality objectives. Eight sewage treatment plants discharging to the Bay and immediately upstream in the Trent River are now required to meet effluent phosphorus levels of 0.5 mg/L during the critical months of May and October and the Agreement target of 1.0 mg/L during the rest of the year.

Wisconsin Department of Natural Resources surveys of Fox River pulp and paper industries revealed the discharge of 105 organic compounds, 20 of which are on the United States EPA toxic substance priority list. Wisconsin officials reissued discharge permits requiring industry to identify the sources of these substances and to propose corrective measures. United States EPA and Wisconsin officials are currently considering additional permit requirements to control the discharge of the toxic substances.

Lake surveys before and after operation of major industrial facilities in the Nanticoke, Ontario area provided a basis for decisions on the treatment system design and outfall location requirements for Stelco steel mills. The surveillance information is also being used in the planning of sewage facilities to serve the community which is expected to grow as a result of the industrial expansion.

Water quality surveys during the early 1970s in the Cleveland area of the Cuyahoga River demonstrated the need for more stringent industrial and municipal effluent controls. As a result of water quality studies, Republic Steel was required to install carbon column treatment for its blast furnace and coke plant effluents, a requirement which was more stringent than the best practicable treatment technology required nationally. Current water quality data show that the dissolved oxygen problem associated with ammonia still exists in the Cuyahoga. Further treatment by the Republic Steel facility may be required to meet water quality and best available treatment technology requirements for ammonia.

A toxic chemicals problem in the Niagara River was identified by the surveillance program, and the International Niagara River Toxics Committee has been established to develop long-term plans for reducing discharges of contaminants.

In conclusion, surveillance in its present form represents a viable realistic program incorporating the experience of past activities in this field with a state-of-the-art surveillance technology and satisfies the requirements of the 1978 Agreement. The program is a framework around which joint international surveillance activites can be conducted to meet current goals and can be readily modified to address new problems as they arise.

Response of Lakes to Remedial Programs

As indicated earlier, environmental measurements in the Great Lakes basin are made on a continuing basis to assess compliance with the general and specific objectives of the Agreement, to evaluate the effectiveness of remedial programs, and to anticipate whenever possible the changing trends in water quality and the emergence of new problems. On reviewing these assessments, it becomes apparent that both the problems and the responses occur at three distinct levels: site-specific, lakewide, and system-wide. Traditionally, attention has naturally focussed on site-specific problems but, with more and improved scientific investigations, lakewide and systemwide problems have been better defined and the need to address them becomes more apparent. Significant steps in this direction have already been taken in dealing with eutrophication, a lakewide problem for the Lower Lakes. More recently, with the widespread contamination of fish and sediments by toxic chemicals, a systemwide problem has been identified.

During the 1970s site-specific "problem areas" were identified across the Great Lakes basin. These problem areas were defined as any locality where Agreement objectives were exceeded or desired water uses could not be achieved. The main drawback with this approach was that it lacked a consistent assessment of the problems and usually relied only on water quality data. In a new perspective, the IJC has initiated a process to establish "areas of concern" based on environmental quality data, and to evaluate these areas with uniform criteria. In this way, the descripion and evaluation of a problem area provides a more complete perspective on the issue. Available environmental data – fish, biota, sediment and water – are now being used to provide as complete a description as possible for each area.

In the 1981 Report on Great Lakes Water Quality, prepared by the Great Lakes Water Quality Board, a lake by lake inventory of "areas of concern" was provided wherein a total of 39 such areas were identified as requiring further remedial programs. Although these areas constitute only a relatively small portion of the total basin area, they contain a large percentage of the basin's population and industry and the concentrated loading points for many pollutants. This is not to say that some progress has not been made. In many cases, pollution levels have been substantially reduced. A clear response to remedial programs implemented by both countries has been observed in nearshore areas of Lakes Erie, Ontario and Michigan, where significant decreases in phosphorus concentrations and accompanying reductions in algae growth were found. High loads of DDT in eastern Lake Michigan, mercury levels in western Lake Erie and levels of PCBs, DDE and Mirex in Lake Ontario have also decreased.

In other areas, however, minimal improvement in water quality has been realized despite the implementation of effective pollution control programs. Much of this occurrence is due to extraneous factors such as the continuous release of residual contaminants from sediments or due to the limited flushing action in some areas of the basin. In such cases some delay is therefore expected before equilibrium with external loadings is reached.

In summary, while there have been numerous delays in the development and implementation of programs on both the U.S. and Canadian sides of the boundary, these efforts represent the greatest undertaking ever made by man to reverse a serious case of environmental degradation. As recent monitoring studies have shown, there is evidence that the Great Lakes ecosystem is responding to the controls already in place. Both countries are determined that this trend will continue.

Setting Water Quality Objectives For Transboundary Rivers

When a river basin is divided by a boundary, particularly an international boundary, current tendency is toward separate management of each jurisdiction's portion of the basin, subject to the constraint that developments in one jurisdiction must not unreasonably interfere with developments in the other. Water quality objectives at the point where a river crosses the boundary are admirably suited to quantifying the water quality aspect of this constraint.

When agreed to, water quality objectives are the limiting conditions which will protect the uses of a certain waterway. Objectives, which may take the form of a maximum permissible concentration of substances such as trace metals, maximum and minimum limits for pH, a minimum acceptable dissolved oxygen concentration, or a narrative statement such as absence of floating debris, were discussed in detail in Canada Water Year Book 1979-80.

Applying Water Quality Objectives

Water quality objectives have been useful in resolving water quality conflicts, as evidenced by their continued and expanded use in many basins where conflicts have occurred. If water quality objectives are established in advance of extensive development, many of the user conflicts, and much uncertainty in predicting ultimate costs of these developments, can be avoided. For example, two recent boundary water projects in western Canada – the Cold Lake project, and the thermal-electric generating station on the Poplar River – have illustrated the value of early consideration of the consequences of development and effluent discharges on the receiving water.

The Cold Lake Project: This proposed oil sands project is located at Cold Lake, Alberta, on the Beaver River, a major tributary of the Churchill River. The project is designed to recover bitumen from steam-injected wells, and will produce significant amounts of waste, approximately 1.8 units of waste for each unit of crude oil produced. The developer initially considered the possibility of discharging a large portion of the wastewater into the Beaver River a short distance above the point where it flows from Alberta into Saskatchewan.

At the request of Alberta, the Prairie Provinces Water Board (PPWB) which serves as a forum for notification and discussion of water resource projects with potential interprovincial implications, reviewed the Cold Lake project early in the planning stage. Also, water quality objectives had been set for interprovincial border crossings in 1973, and steps were being taken by PPWB to adopt revised, site-specific objectives at about the same time that the Cold Lake project was being planned. This situation had two consequences. First, it meant that there was a considerable amount of data already available to reveal the natural water quality at the border, such data being essential both for the setting of sound objectives and also for compliance monitoring when objectives were in place. Second, it meant that as soon as the initial plans were elaborated to the point where the effect of the effluent on the receiving water could be estimated, the changes forecast could immediately be compared to the objectives. It soon appeared that the process as originally envisaged would cause the water quality objectives at the Alberta-Saskatchewan boundary to be exceeded for certain parameters, primarily phenols and some major ions such as sulphates.

The existence of objectives reduced the uncertainty facing the developer, who was now able to determine more precisely the effluent treatment need for his project. Some significant changes were made at the stage when the cost of making such changes is lowest, namely the design stage. The developer was now able to calculate his costs with reasonable assurance that environmental considerations would not cause serious future changes in the project.

The Poplar River Development: The development on the Poplar River consists of a coal-fired generating station at Coronach, Saskatchewan, using coal mined immediately north of the station site. The Cookson Reservoir, on the East Poplar River immediately above the International Boundary, provides water for cooling and steam generation. Potential sources of water pollution from the project included mine dewatering, leaching of boron from disposed fly-ash into ground water, and evaporative concentration of dissolved solids in the reservoir. The main parameters of concern were boron and total dissolved solids, which could be carried downstream and affect irrigation in Montana. There was no specific water quality agreement for the Poplar River at the International Boundary at the time that the power station was designed. As a consequence, there was no incentive to carry out the determination of natural water quality which would have been necessary for water quality objective setting. The project was planned and costed without full knowledge of water quality requirements, and the result was a long and difficult reference to the International Joint Commission (IJC) and added cost for the developer.

One factor which caused problems, according to the IJC report, was the late start in setting objectives and evaluating the impact of the project. By the time that a comprehensive surface water monitoring program had been set up, construction of the dam was already under way and conditions had been altered in the East Poplar sub-basin, preventing the determination of the water's quality before development; attempts to estimate pre-development conditions with a computer model were only partly successful. Also, the only data available on boron toxicity were derived from experiments conducted under very different climatic conditions, and there was no time to obtain site-specific data. Knowledge of the pre-development water quality is necessary to estimate the effects which project operations could have on receiving waters and whether additions of toxic chemicals would adversely effect uses downstream. Natural levels of some elements, for example heavy metals, are already significant in some parts of Canada because of the nature of the rocks and soil in those areas. Further additions from industry could tip the balance and create toxic conditions. In an area with naturally low levels, input of the same amount of chemicals from an industry would probably not produce toxic effects.

The developer was forced to make significant changes in plant design after construction was already under way, mainly to reduce the risk of contamination of surface and ground waters by boron leached from disposed fly-ash. This occurred because levels of boron in the Poplar River basin were already higher than the Saskatchewan and Montana objectives. It is possible that cheaper and more effective measures could have been taken at the design stage. Also, the problems encountered with the first two units may have caused the developer to reconsider the planned construction of two additional units.

The net result is that Saskatchewan gained a power station, but at a cost greater than expected. The delays, the addition of mitigation measures and the possible cutting back of the overall plan from four to two units, have no doubt altered the benefit/cost ratio for the plant.

If water quality objectives had existed beforehand, a power plant would undoubtedly have been built anyway, in view of Saskatchewan's need for power. However, there would have been a better basis for decisions concerning site location and plant design.

The Timing of Objective Setting Is Important

Experience with these projects and others like them has shown that the preliminary planning stage is a critical part of any major development. As soon as it becomes apparent that an important development, capable of leading to significant water-use conflicts, is being seriously considered in a river basin, two things should be done.

First, the adequacy of existing water quality data should be examined. If there is no monitoring being done, or if the current monitoring program appears inadequate, as will often be the case, then an appropriate monitoring program should be instituted.

Second, the adequacy of water quality objectives should be examined. If no objectives exist, then objectives should be adopted as soon as the data on current water quality, and parameters likely to be affected by the development, become available, and the requirements of other users have been taken into consideration. If objectives exist, they should be reviewed in the light of this information, to ensure that users will still be protected when the new development goes onstream.

In the case of the Poplar River Generating Station, the developer made a formal application for water use rights in 1972, and had presumably been studying the question for some years previously. In retrospect, it can be seen that if monitoring had been started on the Poplar River at the International Boundary in 1972, it would have made it simpler to adopt objectives before construction began in 1975. In fact, comprehensive and systematic monitoring did not start until 1975, and even then, high flows, together with overflows of poor quality from a normally noncontributing area in 1975 and 1976, and a start on dam construction in 1977, interfered with the establishment of existing water quality in the East Poplar.

In the case of the Beaver River, it was fortunate that monitoring was already being done and objectives were already available when the project was undertaken.

Objectives May be Subject to Change

The field of toxicology is a continually changing science and, as studies produce more information, a concentration which has been proposed for a toxic chemical may be revised in either direction. This fact should always be considered when agreements on objectives are being drafted.

Objectives are like constitutions; they must embody both a measure of permanence and a measure of flexibility. Developers need a sense of permanence if they are to use the objectives with confidence when they design their pollution control facilities. They need some assurance that the rules will not be changed arbitrarily. At the same time there must be some flexibility so that the objectives can be changed if there is a valid reason for the change and general agreement on the nature of the change. On the international scene, an amending formula is often included in agreements to ensure that objectives are reviewed periodically and revised, if necessary, by mutual agreement, but not unilaterally.

In the case of disputes there has to be some form of arbitrator to whom they can be referred if necessary. In the case of basins along the international boundary, the arbitrator in question is almost invariably the IJC. Within Canada there are interprovincial bodies such as the Prairie Provinces Water Board and provincial agencies such as the Manitoba Clean Environment Commission that have dispute-settling capacities, and also there are courts of law.

Experience so far has shown that such avenues of appeal are rarely needed if objectives have been properly discussed and agreed upon by the parties involved. For example, in the case of the first set of objectives adopted for the Saint John River, some of the objectives were set below the natural levels due to gaps in the data then available. When the data became available later, the objectives were raised accordingly. No international crisis ensued and no developments were known to have been cancelled.

Future Objectives

Water quality objectives have been shown to be a useful tool in water quality management. In future, it would be desirable to set objectives on international rivers in advance of any major developments which could lead to significant international user conflicts. There have been discussions recently between the federal and provincial governments concerning the approach to be followed in setting such objectives, and once finalized, development and the maintenance of river and lake quality should proceed without conflict.

The Poplar River Development was planned and costed without full knowledge of water quality requirements, and the result was a long and difficult reference to the International Joint Commission.

As the industrial world develops, an increasing variety of chemicals are produced to maintain current lifestyles. For example, some 2-4 million different chemicals have already been synthesized, with up to 100 000 in commercial production. Some 9000 of these have an annual production rate greater than one tonne per year. In North America alone, more than 75 billion kilograms of synthetic chemicals were produced during 1977 and the rate is increasing by about 7% per year. New chemicals are being synthesized by the thousands every year and, according to figures presented at the recent Organization for Economic Cooperation and Development meeting in Paris, up to 1000 new chemicals are being brought into production annually. In contrast with the rapid acceleration of chemical production over the last 40 years, the potential consequences posed by such substances have received wide recognition only in the past few years.

Various classes of organic pollutants can degrade biologically or chemically, and may produce varying degrees of oxygen reduction in the water as well as taste and odour problems in water supplies or fish. The main classes of the substances of environmental concern, however, are those which do not readily degrade to innocuous substances and which may bioconcentrate or bioaccumulate in aquatic organisms, or which may be directly toxic to aquatic life or to consumers of aquatic life. Another concern is that some organic pollutants can also be metabolized or changed to a more toxic form in water bodies.

A toxic substance is one which may cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration either in the food chain or in combination with other substances. The toxicity of a substance is not a discrete property but a relative one. High toxicity has meaning only when one substance is compared to another. All elements, chemicals, and mixtures of chemicals produce toxicity after some exposure and time but, to compare toxicities, one must fix either the amount of the toxicant or the period of exposure. For many substances, there is a threshold dose of exposure below which no adverse effects occur, regardless of the length of exposure. Other substances have no threshold; no amount is safe.

The method by which toxic chemicals enter and move through the environment changes from substance to substance. Most areas of the earth experience detectable degradation from atmospheric components. Some toxic chemicals result from the processing of natural raw materials while others may be used as intermediate agents in manufacturing. In other cases, the end manufactured product itself may have an identified problem as in the case of PCBs or DDT. Chemicals undergo a very wide variety of usage patterns ranging from wide area, large quantity uses such as herbicides and pesticides to very specific, low volume uses such as laboratory analytical chemicals. These differences in levels of use add an extra degree of complexity to the developing of control philosophies for, although one chemical may be highly toxic, it may have a very low or controlled usage while another less toxic chemical, because of its high usage, may be of much more ecological concern.

In assessing the effects of a toxic substance, there is a need to test not only for direct and immediate effects but also to determine what will happen after chronic exposure. This latter aspect is one of the greatest scientific challenges today since it has generally been beyond analytical capability to measure these longer-term or second-generation effects accurately. In fact, the movement of chemicals through the food chain and the effects which can result from bioaccumulation have been documented only after the fact, in most instances in the last ten to fifteen years. Even today, it is difficult to show, using current toxicological methods, the effect that long duration exposure to a chemical has on a species or an ecosystem. It is harder yet to develop the capability to measure or predict the effects that combinations of chemicals can have in nature.

Acceptable Residue Limits

Unwanted accumulations of substances in biological tissues are referred to as residues. Residue formation, and bioconcentration potential, can be predicted either by analytical measurements or by calculations from chemical structure. Neither is as accurate as direct measurements from either laboratory exposure or field monitoring, but both are worth considering as a first step, given the current lack of information. Thus, it is possible to predict how much of a substance, for example, PCBs, an organism can absorb. But it will not be especially useful unless a judgement can be made on the exposure levels that are acceptable without causing harm to that organism. This requires animal data for chronic exposure that can be extrapolated to human beings or epidemiological data. Canada and the United States are tackling this problem jointly in studies of fish in the Great Lakes basin. The section which follows demonstrates the need for much more information in this area.

Human Health Effects

While toxic substances can affect all forms of life in the ecosystem, the effects on aquatic life, especially fish, often receive more attention from the media and the public than other biological effects. Man, too, is a part of the ecosystem and will be affected by events occurring in it. An example dealing with Great Lakes water quality is indicative of the potential danger to human health.

Two of the principal routes for human exposure to hazardous substances in waters of the Great Lakes are through drinking water and eating fish. A study completed by a scientist of the Michigan Department of Public Health examined the correlation between PCB residues in Lake Michigan fish and concentrations of PCBs in the blood of residents consuming such fish. This study does not provide data to show whether the intake of PCBs causes health effects. It does demonstrate, however, that the higher PCB levels found in the blood of those eating large quantities of fish correlate closely with the PCBs in the Lake Michigan fish. Many other animal studies show the ease of PCB uptake from food and leave little doubt that the correlations are not due to chance.

The crucial question in this study pertains to the effects on humans. This questions is currently being investigated by ongoing studies, the results of which are not yet available. However, two conclusions can be made with a reasonable degree of confidence. First, hazardous substances that occur in the Great Lakes water and bioconcentrate in fish can be traced through food chains and found in humans consuming the fish. Second, consumption of sport fish can be a significant source of enhanced exposure for select populations, and is a source that may not easily be controlled by present regulatory efforts.

To the extent that the suggested permissible total cumulative intake by humans of 5 ppm of PCBs established by the U.S. Food and Drug Administration is valid, these select populations will obtain such a dose in a little over four years rather than in a lifetime. This example demonstrates that there are at least small populations exposed to higher than average risk that may not be adequately protected by nationally based limits because the source of exposure is not controlled by any regulatory agency or because consumption is well above the averages upon which the allowable food concentration is based. This problem was highlighted in the 1980 Great Lakes Science Advisory Board Annual Report to the International Joint Commission.

The Federal Toxic Chemicals Management Program

Some substances are so dangerous to the ecosystem that their production and use should be banned. Other substances must be managed in such a manner as to keep them out of the environment. Still other toxic substances will have to be applied within the environment, but under controlled conditions.

As with most issues dealing with society's well being, the costs of managing toxic substances can be determined fairly readily. The cost of not controlling the use of toxic substances is more difficult to measure but it can be truly significant, as witnessed by closure of east coast commercial swordfishing because of mercury contamination; English-Wabigoon River mercury pollution; restriction of the Great Lakes fisheries due to PCB contamination; and high cadmium levels in New Brunswick lobster. In seeking to meet this enormous challenge, Environment Canada is developing an assessment and control program framework, basically a system of steps which, when taken together, will lead to effective reduction of existing toxic chemical problems and the prevention of new ones. The steps are as follows:

Environmental Measurement – monitoring and surveillance, entailing measurements of the incidence and accumulation of specific chemical substances.

Inventory – the recording and interpreting of commercial information on toxic chemicals (quantities, locations, points of release).

Characteristics – research on pathways, transformations, chemical characteristics, bioaccumulation, and toxicity to biota (including man).

Assessment – a series of steps including, most often, a preliminary assessment based on initially available data identifying the further measurement, testing, surveillance or research required for a final assessment.

Plans of Action – to be developed to provide an appropriate response to the assessed threat.

Evaluation of Effectiveness – to determine whether or not the problem was reduced or removed and to modify the control procedure in order to improve its effectiveness in dealing with future problems.

To administer this program at the federal level, a senior committee within Environment Canada has been set up under the chairmanship of the Assistant Deputy Minister, Environmental Protection Service. To assist in carrying out the assessment function, Environment Canada has established a permanent Toxic Chemical Management Centre which will have full-time staff plus experts seconded for specific full-scale assessments.

There is already within the various levels of government a variety of specific programs which can contribute to effective management of toxic chemicals, even though their goals entail other priorities. Included are Consumer and Industrial Products Control, Water Pollution Control, Occupational Health Protection, and Food and Drug Control. A number of these programs are operated under separate legislative mandates designed to fulfil a specific purpose. Because of these legislative variations, it should be possible during the development of the Plan of Action to recommend which program will provide the most effective control for a particular toxic chemical.

In addition, and perhaps most importantly, Environment Canada, under the direction of the Minister, is developing new legislation designed to consolidate within existing Acts the means to better address today's environmental challenges, with special application to toxic chemicals. The approach will become a multi-media and multi-participant one, with Environment Canada acting in concert not only with other federal and provincial agencies, but also with the affected industries and the general public.

In Canada and elsewhere, the many links between water use and energy development have led to an emerging realization of the importance of evaluating water resource factors in relation to energy development. A few isolated Canadian studies have connected the two topics but, to date, a consistent effort has not been made to research the subject, nor to define the overall problem in national terms. One difficulty has been the fact that water and water environmental problems are local in character. The approach has been to do small-area studies on energy aspects, among a host of other concerns which may arise. Thus, a grasp of the larger scope of the issue has not been forthcoming. Elsewhere, in the United States for instance, the problem has been more actively recognized.

The major renewable energy source in Canada for which water is an essential presence is hydroelectric generation, either in conventional development or in tidal power installations. The non-renewable energy industries, for which water quantity and quality are increasingly important, are thermal-electric generation; exploration, development and processing of oil and gas; heavy water production; coke-making; and coal and uranium mining. As well, to a growing extent, water is employed as a storage medium for heating and cooling in distributive solar or energy-efficient systems in buildings. The latter may involve up to 7-8 million litres of water per system.

The Canadian energy industry has experienced rapid growth for thirty years. This trend will continue over the next decade, as new projects aimed at energy self-sufficiency come on line. An indication of its scope can be found in data on capital expenditures. Energy-related capital requirements have been forecast by Canadian business sources to average some $20-25 billion per year in 1980 dollars. This represents about 22% of all private and public investment in Canada or more than 6% of Gross National Product.

Because of the ties between water and energy, such rapid, large scale development will have significant implications for water management. An on-going increase in energy's share of water supply and water impacts can be expected. The scope of the change can be seen from sectoral projections of water use by energy industries and others to the years 2000 and 2020. Also, changes in the ways that water is applied within the energy sector are expected to bring new problems to consider.

Projections

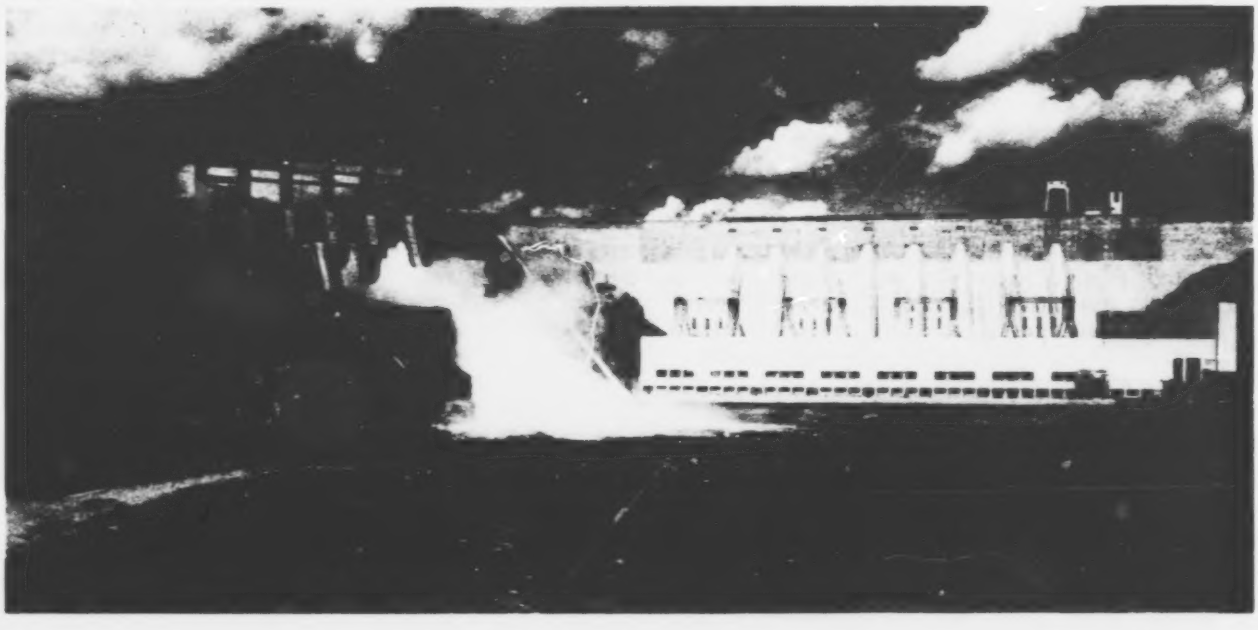
The following Tables (13 and 14) give projections of energy and non-energy water use to the year 2020 for 1) Canada, and 2) the Prairies. The latter table covers a region of critical interest in both energy production and water resources management. The prairie region is characterized by a variety of energy fuels in abundance, a dry climate and a relative scarcity of water resources.

Although it was not possible to break the prairie forecast down by sub-basin, it can be said that perhaps 75-80% of regional water withdrawals in the year 2000 will have to come from the Saskatchewan-Nelson basin. As well, this large river system provides nearly all the hydro sites in the region. The southerly Missouri, Milk and Souris basins also support major water uses, and are already over-committed.

In Table 13, the projected water demands within the energy industry in Canada are segregated under the headings renewable and non-renewable energy resources.

Water used for renewable hydro energy appears first because it is such a large and important water utilization from several different aspects. Hydro installations must have huge quantities of water available, and consequently many large water developments in the past have been single-purpose hydro projects, often with insufficient regard for other water or land users. Although technically a non-

The major renewable energy source in Canada for which water is an essential presence is hydroelectric generation.



consumptive water use, hydro affects the supply to other users by regulating streamflow and by encouraging greater evaporation of stored water. In the years ahead, hydro will continue to be of prime importance to Canada because it is the only major renewable environmentally clean energy form and it conserves scarce fossil fuels. By the year 2000, Canadian hydro generation could be supplying the thermal-electric equivalent of some 905 million barrels of crude oil a year. New hydro capacity will likely continue to come on line after the year 2000 but a downward shift is assumed in hours of use overall, as other energy sources take over a greater part of Canadian base loads.

Water used for non-renewable energy has been largely for cooling at thermal generating stations and for producing heavy water for nuclear plants. However, Table 13 shows that water also has an important use in the extraction and processing of fossil fuels.

Electrical generation water use includes water intakes for condenser cooling and boiler makeup at conventional and nuclear thermal steam power plants. The projected growth of thermal plant water use is conservative because of assumptions made. A forecast was made of conventional thermal and nuclear power generation; then a once-through water use basis with a given temperature rise was assumed; and improved average heat rate and water-saving, closed cooling systems were introduced for a portion of new plants built in future years. The assumed water savings through new technology may not be realized, however. The estimate of water for heavy water manufacture allows for domestic heavy water needs for both initial start up and later for topping up of CANDU plants, but the production of heavy water for export was not considered.

In terms of fossil fuels, Table 13 shows the extractive use of water in oil and gas production, with an allowance for increased application in secondary and tertiary recovery techniques; the foreseen production of synthetic crude oil from oil sands and heavy oil by the mining, hot water and in situ steam processes, coal mining water for beneficiation (washing and preparing the coal); natural gas processing and oil refining; and coke making.

	1980	2000	2020
1. Renewable Energy Uses			
Total water use for hydro generation	8 250 000	16 983 000	21 369 000
2. Non-Renewable Energy Uses			
Thermal generation(2)	48 400	143 400	397 900
Other Energy Uses Fossils-Extraction & Processing			
a) Petroleum Gas, Oil Sands(3)	4 372	6 861	8 571
b) Coal Mining and Coke Plants	71	157	271
c) Possible Developments (coal liquification, slurry pipeline, solar storage	—	1	332
Subtotal (Other Energy Uses)	4 443	7 019	9 174
Total (Non-Renewable Energy Uses)	52 843	150 419	407 074

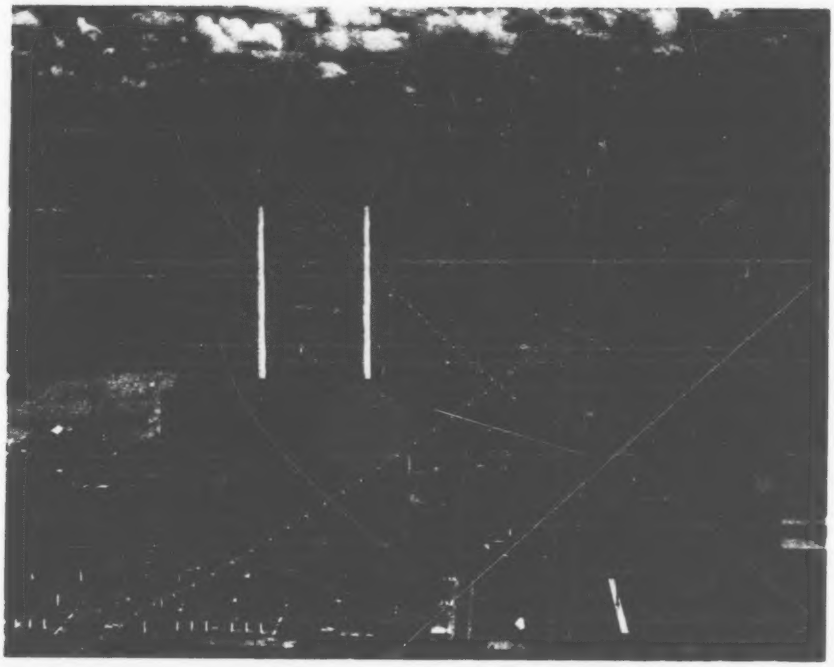
(1) Refers to water withdrawals, not consumption.
(2) Includes water used to manufacture heavy water; allowance has been made for increased use of closed condenser cooling systems.
(3) Allows for increased water use in secondary and tertiary recovery in oil fields, and also for greater in-plant recirculation of process and cooling water in refineries.

New applications in which water may be employed by the year 2020 include coal liquefaction and gasification, and slurry pipelines. The water projection is supposition only, and is for a minehead liquefication plant and a 400-km slurry pipeline located in the prairie region. The liquefication plant, which would involve some 8-9 million tons of sub-bituminous coal feed annually, represents an insignificant contribution to national energy self-sufficiency at that future time.

Table 14, like Table 13, gives projected water uses in the non-renewable energy field throughout Canada but extends the earlier table by including current and projected water uses in non-energy uses also. As seen in Table 14, total water withdrawals are expected to nearly quintuple over the next 40 years, due mainly to the needs of nuclear power plants. Even with greater use of recirculating water systems, thermal power plants are bound to need an even larger portion of the water available, as reliance on hydro declines at the same time as electricity captures larger portions of the energy consumption market. By the year 2020, thermal power plants are expected to need almost three-quarters of all withdrawals, and others in the energy group should hold steady at 2-3%, while withdrawals by non-energy users should decline proportionally.

Even more interesting are the local and regional implications of increases in energy-related water use. Eventually, the sub-humid Prairie Provinces, with their extensive energy resources, will bear the greatest impacts of water usage versus energy development. Table 14 also gives regional projections to the year 2020. The table shows that total water demand in the prairie region can be expected to increase more than three-fold over the next four decades. Non-electric energy water use – with commercial sized synthetic fuel plants and a slurry pipeline included – is expected to double. Water use for steam-electric generation is expected to increase 2.5 times by the year 2000, even if water-saving cooling systems are in use, and to nearly double again thereafter. It is also highly probable that new hydro plants will come on line in Alberta as well as in Saskatchewan and Manitoba, before the year 2000. In the first decade of the 21st century, most prairie hydro sites capable of development should be commissioned.

By the year 2020, thermal plants are expected to account for at least **52%** of total prairie water demands.



	1980		2000		2020	
	mL/d	%	mL/d	%	mL/d	%
1. CANADA						
Energy Uses						
Thermal Generation[1,2]	48 400	43.4	143 400	[illegible]	367 [illegible]	74.1
Other Energy Uses	4 440	4.0	7 010	2.8	8 176	1.7
Sub-Total	52 840	47.4	150 410	61.5	[illegible]	75.8
Non-Energy Uses[3]	[illegible]	52.6	[illegible]	38.5	[illegible]	24.2
Total	111 [illegible]	100.0	[illegible]	100.0	[illegible]	100.0
2. PRAIRIE REGION						
Energy Uses						
Thermal Generation[2]	[illegible]	37.5	[illegible]	[illegible]	[illegible]	82.1
Other Energy Uses	[illegible]	3.1	[illegible]	[illegible]	[illegible]	3.0
Sub-total	[illegible]	42.6	[illegible]	[illegible]	[illegible]	85.1
Non-Energy Uses[3]	[illegible]	57.4	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(1) [illegible]

(2) [illegible]

(3) [illegible]

By the year 2000, an interesting shift will occur in the allocation of water withdrawal uses in Canada as a whole (Table 14). From levels of approximately 47% for the energy group and 53% for non-energy uses, the ratio in favour of the energy sector will change to 62% versus 38% in the year 2000 and to about 76% versus 24% in the year 2020.

In the Prairie Provinces, the shift to the energy sector will be equally dramatic even if water conservation assumptions prove correct (Table 14). In the early 1970s, thermal stations had the greatest water withdrawals, with 44% of all water taken in. In 1980, thermal power plant needs were estimated at about 38% of all water intakes due to use of cooling ponds, while all energy applications accounted for some 43% of total withdrawals. By the year 2020, thermal plants will account for at least 52% of the prairie water demands. Without intensive recirculation of cooling water, thermal plant withdrawals would be at least twice as large in 2020.

When compared with the average water supply available, 230 000 mLd of reliable annual flow, prairie water supplies appear adequate. Nevertheless, overviews are deceptive, and a true picture of demand-supply water balances for energy development can only be seen by investigating at the basin level. With foreseen population and industrial growth, water withdrawals for manufacturing, mining, and agricultural uses can be expected to grow apace, at least doubling every 40 years.

Effects on the Environment

It is clear that, in the future, electric power generation will have a much greater effect than all other energy-related water environmental concerns, simply because of the huge volumes of water taken in, used, and released.

Hydro development effects on water quantity and quality are mainly related to the reservoir interfering with the natural flow regime, or flooding land and impeding other resource users.

Thermal steam power plants withdraw huge amounts of water for condenser cooling. They consume little but discharge it in a heated condition. The large intakes inevitably suck up and harm small biota existing in the water, while the thermal discharges can have other deleterious effects. Water pollution occurs from boiler or cooling tower "blowdown", to clear out dissolved impurities, as well as from fly ash and bottom ash handling systems in fossil-fueled thermal plants even though ash lagoons are usually designed to limit contamination through seepage to the fullest extent possible. Also, should flue gas desulphurization become common, significant amounts of intake water would be involved in the most promising technologies. The flue gas and scrubber sludge makeup water for wet flue gas desulphurization of low sulphur subbituminous coal, for example, can amount to at least 500 L of water per ton of coal fuel, and the water is consumed. Although relatively small in comparison with cooling water intake, flue gas desulphurization can increase a power plant's consumption of water by some fifty percent.

In nuclear plants, the Canadian CANDU nuclear reactor is considered well-designed and efficient. It uses natural uranium and heavy water (deuterium) under pressure both as modulant and coolant. The condenser cooling system uses about 50% more coolant per kWh than fossil-fueled plants because it throws off more waste heat. Heavy water is obtained by separating the deuterium from ordinary water, in which it exists in a ratio of 1 part per 7000. As a result, vast quantities of natural waters are required in the production of heavy water but the water is returned to its natural source unimpaired.

Oil and gas, oil sands and heavy oil, and coal mining all exert impacts upon land and water resources. In coal mining, there are problems with disturbance of ground- and surface waters if the seams cross stream beds, and also with polluted drainage and leaching from spoil piles. Water is used in coal washing and beneficiation (about 1,800 L per metric ton of coal), although use of closed systems reduces new water needs to intakes for makeup. Wet precleaning of coal to remove sulphur and ash, and improved fluidized bed technology for clean combustion, using variable amounts of water, will be available by the year 2000. In uranium mining, low quality water is employed for dust control and beneficiation.

Water is used consumptively as a secondary recovery technique for deep-well injection in order to maintain sufficient pressure to force crude oil to the surface. Either briny or fresh water is used, and all of it is considered lost to further use.

Oil sands mining involves a hot water extraction process that requires vast amounts of water and produces large amounts of contaminated water (tailings). Alternative in situ processes for oil sands and heavy oil make use of high pressure steam to turn the in-place mineral into a fluid for recovery by pumping. Water is also needed to transport residual sand to tailings ponds, and for steam-electric generation. If complete hydrogeneration is required to market heavy oils, more water will be needed to produce hydrogen by steam-methane reforming. Gas processing requires water for cooling purposes, while oil refining uses in-process and cooling water.

Coke-making in Canada is mainly associated with the steel industry which employs water for cooling ovens, gas and equipment, scrubbing gas and recovering by-products, and quenching coke on discharge from ovens. About one-eighth of total gross water use of an integrated steel plant is used in coke making, and pollution may result from still water and quenching effluents, gas cooler water and leaks in cooling coils.

Synthetic fuel manufactured from coal withdraws large amounts of water but does not consume it. Water is employed for hydrogen extraction, cooling, wet waste disposal, and environmental control. Slurry pipelines over short distances may appear in Canada by the year 2000. One technique uses a coal-in-water slurry, with a ground-up coal, water and impactor combined. Dump ponds and water supplies are provided at pumping stations for emergencies. On arrival, the slurry is dewatered, with no liquid discharge. In all, a 75-cm pipe requires more than a metric ton of water to move a metric ton of coal. Besides their high water resource depletion effects, pipelines present a danger from line breaks, with resulting widespread contamination of ground and surface waters. In cold climates, freezing poses an additional problem.

In planning for the development of water supplies for energy-related projects, problems to be considered include scarcity of water, water quality, institutional constraints, competition among users, availability of capital, and environmental concerns. Generally, acceptable solutions to all problems must be found or the needed energy undertaking may be stymied.

During the winter of 1979-80, only one third to one half of normal snowfall occurred in the heavily populated region stretching from Windsor to Quebec City; although millions of dollars were saved in snow removal costs, that winter was a disaster for businesses dependent upon either snow removal or winter outdoor recreation. Water shortage has been a worry on the prairies which suffered a recurrence of drought-like conditions during the period 1976-1980; a very costly aspect of the drought in 1980 was reflected in losses to both the agricultural and forest industries in western and central Canada. On the other hand, the early winter of 1980-81 produced mudslides and floods in British Columbia, high heating bills in eastern Canada, and paralyzing snowstorms in areas of the Atlantic Provinces. These events and others over the past decade have demonstrated society's sensitivity to droughts and floods caused by climatic variations. Food production, water supply, energy demand and other factors have been repeatedly brought under stress, often with disastrous effects in human and economic terms. The conclusion is inescapable; both climatic variability and the prospects of unprecedented change in the world's climate are emerging as critical social, economic and environmental issues for Canada.

It cannot be said that every year produces striking climatic anomalies, nor are all areas equally vulnerable. Undoubtedly, the climatic anomalies that have caused the greatest socio-economic impacts in Canada have been droughts. The drought during the depression years of the 1930s was a very significant event in Canada's history. But Canadians also can be affected by climatic anomalies in other countries. Drought and frost in the wheat producing areas of the Soviet Union and frost in the coffee plantations of Brazil or in the orange groves of Florida can alter the prices of these commodities in Canada quite significantly.

Prospects for weather and climatic modification, directed towards bringing use of the environment into closer harmony with its capacities and with the purposes of man, are not new to science. But man's ability to induce deliberate changes of measurable magnitude by artificial means is still in its infancy. The scale of known operational ability for deliberate weather modification is presently the dissipation of supercooled fog and stratus from an area approximately the size of an airport. On a large scale, the inadvertent modification of the weather and climate by such influences as the products of urban development, surface modification for purposes of agriculture and silviculture, and compositional changes of the atmosphere through the combustion of fossil fuels, CO_2 emissions and other exhaust gases are quickly becoming of sufficient consequence to affect the weather and climates of large areas and ultimately the entire planet. Clearly, man could be changing the global climate to an extent never before imagined, and Canada's geographical location makes it among the areas of the world likely to experience the greatest climatic changes.

The implications of climatic variability have prompted the Government of Canada to set up the Canadian Climate Program. But Canada is not alone in this endeavour. The United States has initiated a program and so have the United Kingdom, the Federal Republic of Germany, Japan and many other countries. On a global basis, a World Climate Program was established in 1979 which calls for all nations to establish workable methods to make better use of climatological information in all sectors of activity, to identify ways by which the adverse impacts of climatic change and variability may be mitigated and to identify advantages of any climatic opportunities arising.

The Canadian Climate Program took on a formal structure along with increased activity in 1978 when Environment Canada's Atmospheric Environment Service formed the Canadian Climate Centre and a Climate Program Office to provide a centre of expertise and a focus for climatological activities. Following the creation of the Climate Planning Board and the Climate Advisory Committee, a series of workshops and surveys was held to assess the present levels of climatic activity and projected needs. A major workshop on water resources (including wildlife) was held in Edmonton in February 1980. In 1981, the Canadian Council of Resource and Environment Ministers sponsored a Climate Change Seminar which focused on climatic variations and their impact on natural resources. At the seminar, the provinces endorsed the concept of a Canadian Climate Program and identified needs for enhanced application of climatological data and information.

The general objectives of a comprehensive Canadian Climate Program are:

1) to provide the climatological information required to assist in meeting Canadian social, economic and environmental objectives;

2) to integrate and provide a focus, a stimulus, and an accountability for Canadian climatological activities; and

3) to be consistent with, and supportive of, the major goals of the World Climate Program and Canada's interests in related international programs.

Essential to realizing these objectives are four program components which address basic activities and needs.

1) A Data Component is required to provide the climatic and climate-related data that are essential to achieving the goals of the Canadian Climate Program.

2) An Applications Component is required to develop methodologies and systems for applying climatic knowledge in support of the attainment of Canada's social, economic and environmental goals, including those in water resources.

3) An Impact Studies Component is required to develop an understanding, suitable methodologies and the ability to predict the consequences of climatic anomalies on society, the economy and the environment as required for the evaluation of alternative policy strategies.

4) A Research Component is needed to determine the extent to which climate and the extent of man's impact on climate can be predicted, and to develop general understanding of the climatic system.

While the Canadian Climate Program will influence numerous subject areas in related fields, it is discussed only in terms of water resources in following sections.

Climate and Water Resources

What is the link between water and climate? Hydrology has a prime role within climatic programs since water, like climate, is pervasive and affects life processes and most human activities.

Atmospheric processes are reflected, though modified, in the hydrologic process. Water resources planners and managers are intimately concerned with weather information, climatic definition and associated anomalies and impacts.

Water resource projects cannot be designed and managed rationally without taking account of climatological and hydrological data. Economic and social development entails a wide variety of such projects, for example: food production calls for projects associated with agricultural water supply, irrigation and inland fisheries; drinking water entails urban and rural water supply projects; health and security employ flood forecasting and regulation as well as the prediction and control of water quality; and, industry and commerce depend upon industrial water supply, hydropower and inland navigation projects. The use of climatological data for such projects is not a new concept, but their application in the past has been restricted. The Canadian Climate Program is expected to remedy this.

Water is central to most climatic change problems, whether associated with man's activities or natural variability. Climatic warming, for example, has major significance for Canada and is reflected in the alteration of the break-up and freeze-up regimes of northern rivers; increased aridity in southern regions requiring adjustment of water systems, allocations and regional land-use and development; and change in extent of snow cover and ice fields and the resultant effect on timing and amount of snowmelt runoff and subsequent effects on flood flows, hydro production or water supply. Man's activities in diverting northern rivers into more southern regions have large potential impacts on Arctic sea ice conditions and ultimately on Canada's hemispheric climate. Such major impacts must be assessed. Climatic risks have been a traditional design problem and the potential consequences of extremes and persistence, as well as natural variability, must be known if hydrometeorological data are to be transformed into information useful for planning and policy making.

More specifically, climatic change and variability could change water supply intended for domestic, industrial, agricultural and other consumptive uses as well as non-consumptive fish, hydro and aesthetic uses. Water demands also fluctuate with climate. Water quality could be affected through reduced dilution, temperature changes and biological shifts. Engineering design that does not allow for climatic change could turn out to be less than satisfactory after a change. Examples include spillway designs, flood proofing and storage reservoir sizing. Runoff variability, which is the most difficult parameter in water resources planning, could be augmented or decreased, requiring changed approaches to planning. In addition, there is the equally important problem of the impact of water resource management schemes (such as dams and irrigation) on climate, both on the regional and national scale.

The Action Plan

The overall goal of Water and the Canadian Climate Program should be to meet more effectively the socio-economic needs which depend upon water resource systems through the improved application of climatological data and information. In support of this goal, appropriate measures are needed (a) to enhance understanding of the relationship which exists between climate and water resources owing to hydrological processes (b) to make effective use of climatological information in water resource management (c) to enhance understanding of the impact of climatic variability and change on water resources, and (d) to improve the availability of data.

To meet the needs of the water resources sector in addressing the potential problems associated with climatic variations, many recommendations have been put forward for consideration within the action plan of the Canadian Climate Program. Specific recommendations are given in the Proceedings of the Water Resources Workshop (Atmospheric Environment Service, 1982) and in the Proceedings of the Climate Change Seminar (Atmospheric Environment Service, 1981).

Many of the requirements are related to climatic data and services. For example, there is a need to expand and upgrade the existing hydrometeorological network in data sparse regions where future economic development presents current design and planning problems, especially in northern and alpine regions. There is also a requirement to augment the real time observing network, especially in remote regions and on large Canadian lakes, with automatic stations and to provide appropriate standardization of real-time sensing, transmission and archiving of hydrometeorological parameters. This then means there is need for improved coordination in the collection and cataloguing of all climatic data for Canada in a central and/or regional archive and in a standard readily usable form. Improved access to and delivery from the archive should then follow.

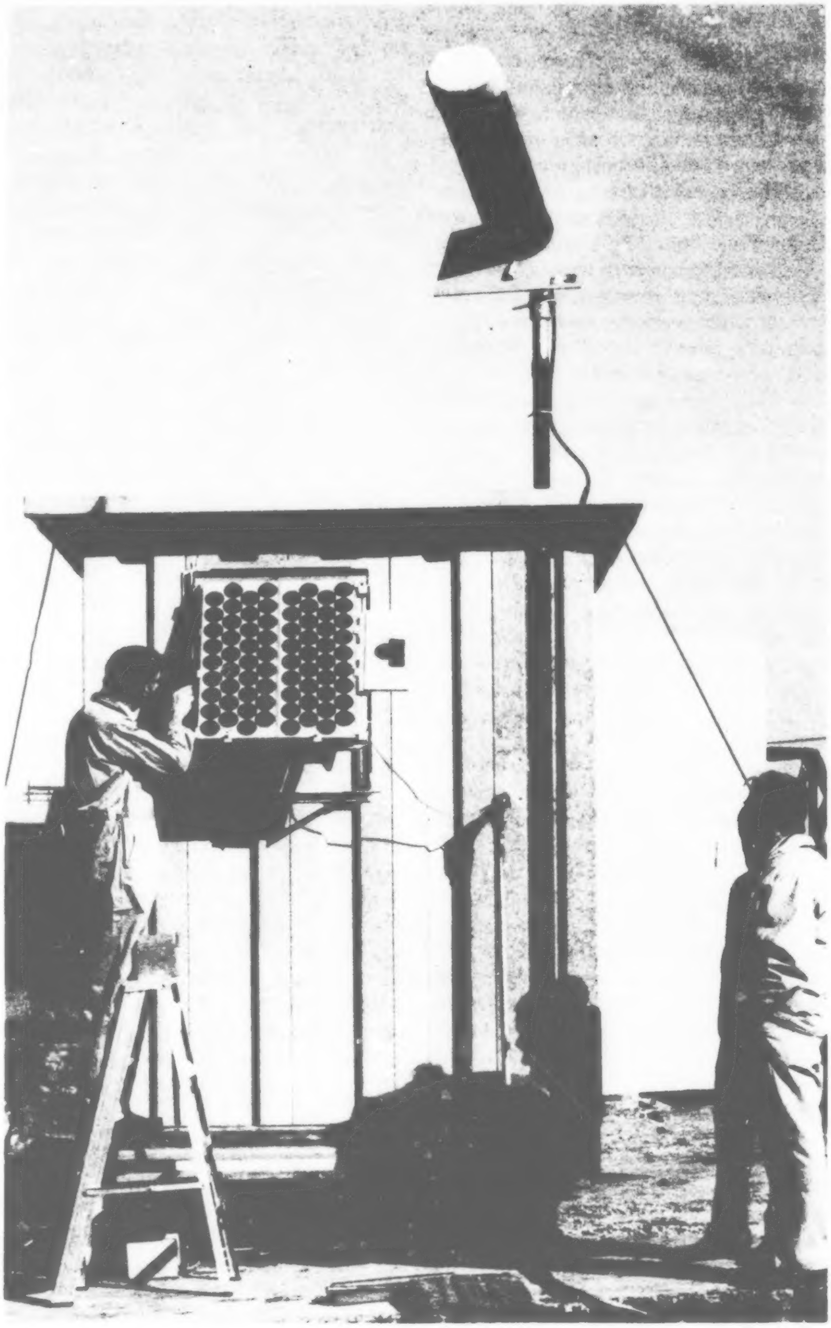
In the area of analysis, there is a requirement to develop and implement climatic data analysis techniques useful to the water resources sector. This might include the monitoring and analysis of water availability (e.g. for drought monitoring), snow accumulation/ablation, soil moisture, or lake evaporation and the development of climatic outlooks, including seasonal prediction of climatic parameters for use in water resources management, wildlife and fisheries management.

The development of good analyses, however, depends on the availability of consistent long-term measurements. The value of data for statistical analyses is frequently greatly diminished because of a lack of continuity in operation, siting, instrumentation and observing practices. Such deficiencies are major impediments to the efficient application of the climatic knowledge that presently exists, and to progress in research. An aspect related to this is the development, calibration and integration of proxy and non-standard data.

In the water resources sector, research and development activities also have been identified for attention. Studies have been proposed which would improve the physical basis for climatic models, and their effective use in streamflow forecasting, on both a national and regional scale. Special projects would be conducted to assess the sensitivity of resource projects and ecosystems to climatic fluctuations, including the impact of climate and the spatial variability of climatic extremes on water resource activities, and the development of methods for predicting the onset and ending of extreme water supply conditions such as droughts. Research aimed at the improved measurement and estimation of hydrometeorological parameters is still required especially for point and areal measurements of snowfall, snow cover and snowmelt; basin evaporation and evapotranspiration; and areal measurement of soil moisture. Improved automated measurement systems for the measurement of precipitation, snowpack, temperature, soil moisture, dew point, wind and radiation in remote areas require development and evaluation. Effective techniques need to be developed to integrate radar, satellite, airborne remote sensing and ground-based measurements for determining the areal distribution of climatic variables, particularly precipitation, snow water equivalent, soil moisture, and lake temperature/evaporation. Finally, the collection of all types of proxy data should be encouraged and research should be conducted with the ultimate aim of extending historical non-instrumental records, including the linking of proxy data with present climatic and hydrologic conditions.

If most of these needs are to be met, there will have to be improved consultation, communication and education. This means there must be improved coordination and cooperation between agencies in many activities including the planning of observational networks, establishment of regional climatic centres or committees, the standardization of network observations and data publications, and improvement in the transfer of knowledge from research scientists to planners and designers.

Climatic change and variability has and always will have broad impacts on water resources management. Much is being done to utilize the climatic data base in water resources management. Cooperation and coordination of activities through the Canadian Climate Program can only make climatic data and analysis more useful and therefore more effective in water resource management.



This structure with its own solar power supply is equipped to transmit hydrometeorological data from remote regions to satellites overhead.

The aim of this section is to highlight the extent and type of overseas involvement at the government level in Canada. The contributions by Canada's university and private sectors are substantial but the cross-sectoral nature of water and the diversity of Canadian interests in overseas activities made it impracticable to attempt to compile a comprehensive review of such activities within the time and space available. Nor is the review of government activities comprehensive.

Input has been restricted for the most part to the broader aspects of water resource management. That final step which links the resource to the user – the well, pump, turbine, dam, reservoir, water treatment plant, etc., has not been addressed – with the exception of a few particularly noteworthy large scale water supply and purification projects. Notwithstanding these limitations, the authors would be remiss if mention were not made of the valuable contributions made by the many Canadian organizations through the provision of such facilities to the millions of deprived peoples in overseas countries.

Most formal international liaison occurs through the Department of External Affairs. The National Research Council is also the focus of international exchange, through its liaison with the international scientific community. Provincial governments, as they realize the potential for mutual benefit, are also sharing more of their experiences on common problems directly with overseas nations. Canadian involvement is either on a one to one basis with another country, or multilaterally through a maze of international organizations.

In instances where the professional knowledge of an individual is sought, either through a scientific exchange arrangement or on a unilateral basis, the international community has direct access to federal, provincial and private sector expertise, but governments would not normally be committed as a result of any actions taken during such arrangements. In situations where governments are expected to make commitments, for example, at major UN environmental or water conferences, a joint federal-provincial approach is usually in order, the issues often falling within the jurisdictions of both levels of government. However, the federal government is faced with the difficulties of involving the non-federal sectors in the regular business of the formal international policy making bodies – difficulties caused by the rather strict time constraints on the development of national positions and by restrictions on delegation size.

In the absence of a defined policy statement on international involvement, federal participation tends to be guided for the most part by national priorities. But, more and more, Canadians are finding themselves confronted with water problems which are global in nature. Transboundary pollution is commonplace; water quality problems associated with industrial development are worldwide; climatic fluctuations are causing droughts or flooding over vast areas; and acid rain can be damaging to water resources in all countries. These factors are setting the scene for future international cooperation.

It is a common assumption that Canada is contributing more than it stands to gain from this involvement. While this would be admirable if true, Canada's overseas involvement, in particular that associated with scientific and technical exchange, must be viewed as mutually beneficial. Even though it has an advanced water program, Canada does indeed stand to gain by the sharing of common experiences with other nations. Beneficial returns from Canada's contributions to developing countries are harder to quantify; still, there are material and scientific benefits to be gained. At the same time, there is a humane aspect that cannot go unrecognized. World opinion asserts that it is no longer acceptable for the 3 billion or so people in developing countries to be without safe drinking water or decent sanitation facilities or for water-borne organisms to play a large role in the deaths of I0 million people each year from diarrheal diseases, or for 50 million people to be afflicted annually with river blindness or 800 million by malaria. The eradication of such diseases as these is one of the principal aims of the World Health Organization's "International Drinking Water Supply and Sanitation Decade" (1981-1990) to which Canada subscribes.

Some of the more important aspects of Canadian involvement in overseas freshwater activities is given below for three main groups: the United Nations Family, Other Multinational Organizations, and International Scientific Organizations.

The United Nations

By far the largest part of Canada's overseas activity in the water field falls under the umbrella of the United Nations System. Figure 4 depicts the entire UN system while Table 15 indicates the specific organizations with water resource interests and shows the principal points of contact.

United Nations Conferences

One of the more successful methods of focussing world attention on global environmental concerns has been through the series of United Nations conferences. The first, in 1972, at Stockholm, dealt with the Human Environment and issued a declaration, supported by Canada, which called upon countries to recognize their responsibility for ensuring that their activities do not cause environmental damage beyond the limits of their jurisdiction, to cooperate in the development of international laws regarding liability and compensation if such damage should occur, to cooperate on a multi- or bilateral basis to protect and improve the environment, and to recognize the role of international organizations in achieving these aims. The success of the Stockholm event gave impetus to a series of other conferences which had an impact on water interests and in which Canada played a role. These included the UN Population Conference in Bucharest and the World Food Conference in Rome, both in 1974; the UN Conference on Human Settlements (Habitat) in Vancouver (1976); the UN Water Conference in Argentina, and the UN Conference on Desertification in Kenya, both in 1977, the UN Conference on Science and Technology for Development in Vienna (1979); and most recently, the UN Conference on New and Renewable Sources of Energy in Nairobi (1981).

United Nations Economic and Social Council

The UN's Economic and Social Council (ECOSOC) carries out its business by means of Functional Commissions (e.g. Status of Women), Standing Committees (e.g. Natural Resources) and Regional Commissions. This last category consists

[illegible]

ECOSOC	Economic Commission for Europe (Committee on Water Problems)	Environment Canada (ECS)
Unesco	Man and Biosphere International Hydrologic Program	Canadian Committee for Unesco Environment Canada (ECS)
WHO	Collaborating Centre for Surface and Groundwater Quality	Environment Canada (ECS)
WMO	World Weather Watch (Global Observing, Data Processing and Transmission Systems), World Climate Program and the Hydrology and Water Resources Program	Environment Canada (AES)
FAO		National Health and Welfare (FD) Fisheries and Oceans
WFP		Agriculture Canada National Health and Welfare (FD)
IFAD		
IAEA		Atomic Energy Control Board
UNEP	Earthwatch (Global Environmental Monitoring System, International Referral Service for Sources of Environmental Information, International Register of Potentially Toxic Chemicals)	Environment Canada National Health and Welfare (EHD)
IBRD		Canadian International Development Agency
UNDP	Training Programs in Hydrology	Environment Canada (AES, ECS)

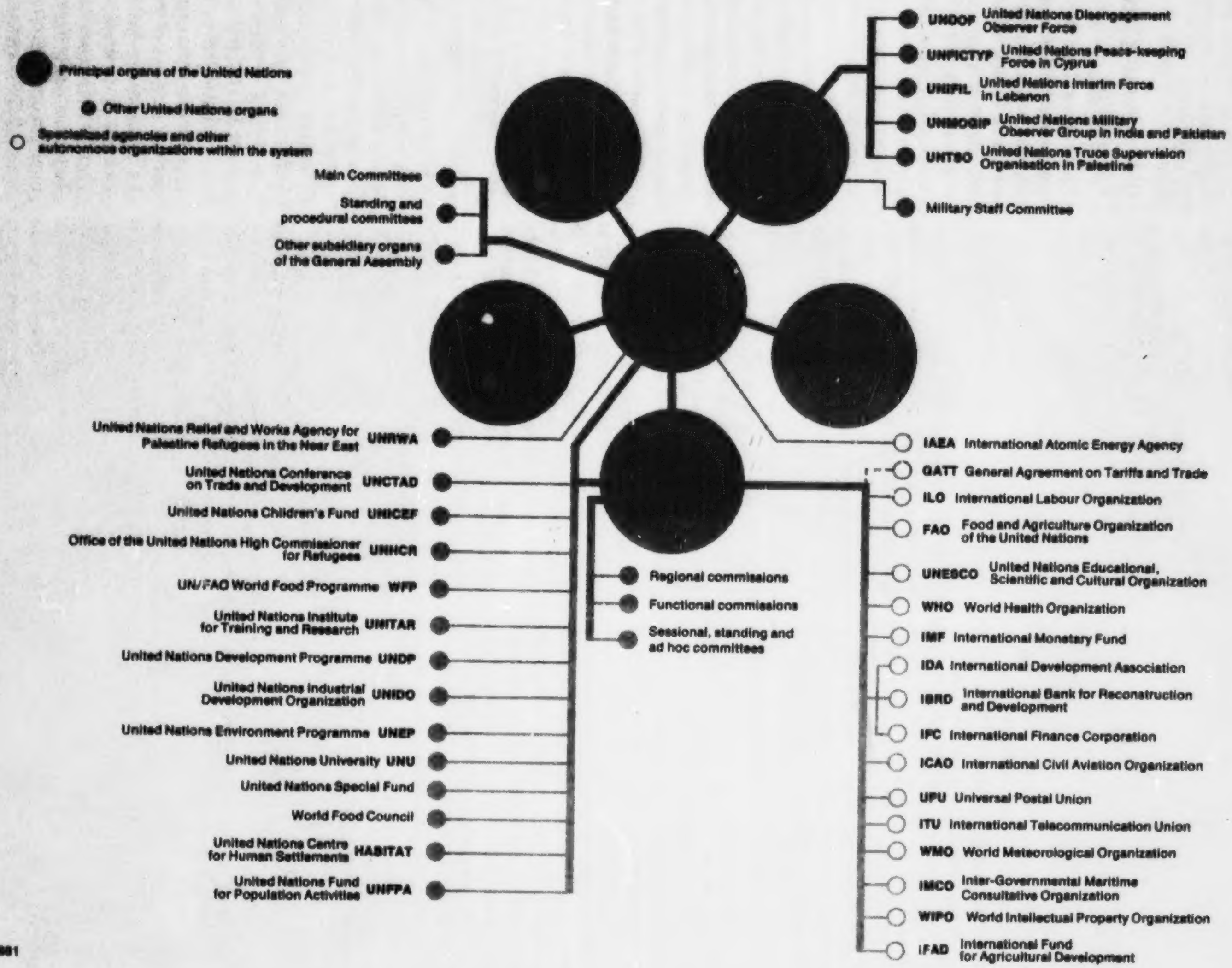
AES – Atmospheric Environment Service
ECS – Environmental Conservation Service
FD – Foods Directorate
EHD – Environmental Health Directorate

of 5 economic commissions (Africa, Asia and the Pacific, Europe (ECE), Latin America and Western Asia) whose aim is to assist in the economic and social development of their respective regions. Canada and the United States have identified the ECE as a body that shares many common concerns and have opted for membership. They are the only non-European members of the Commission. ECE water interests are considered for the most part under its Committee on Water Problems and its working group of Experts on Aspects of Water Quality and Quantity. Canada is represented by Environment Canada on both of these committees. Current areas of involvement include water pollution from animal production, methods for defining water quality standards, drought and flood management, purification of industrial and municipal sewage effluents, conventions and international agreements in the ECE region, and water use and supply. Input is also provided to the ECE high-level annual meeting of the Commission in plenary session and to activities of the Senior Advisors on Environmental Problems and the Senior Economic Advisors. One recent item of significance, after some years of debate, is the accord signed by the Ministers (including Canada's) on the prevention and control of water pollution, including transboundary pollution.

Unesco

The United Nations Educational, Scientific and Cultural Organization has the most varied program of all of the UN Specialized Agencies. In the scientific field, Unesco's principal aim is to advance the cause of science and much emphasis is placed on the need to correct the imbalance in trained manpower. There are two major programs in the water sector.

The International Hydrology Program: As a follow-up to the successful In-


● Principal organs of the United Nations
● Other United Nations organs
○ Specialized agencies and other autonomous organizations within the system
Main Committees
Standing and procedural committees
Other subsidiary organs of the General Assembly
UNDOF United Nations Disengagement Observer Force
UNFICYP United Nations Peace-keeping Force in Cyprus
UNIFIL United Nations Interim Force in Lebanon
UNMOGIP United Nations Military Observer Group in India and Pakistan
UNTSO United Nations Truce Supervision Organisation in Palestine
Military Staff Committee
United Nations Relief and Works Agency for Palestine Refugees in the Near East UNRWA
United Nations Conference on Trade and Development UNCTAD
United Nations Children's Fund UNICEF
Office of the United Nations High Commissioner for Refugees UNHCR
UN/FAO World Food Programme WFP
United Nations Institute for Training and Research UNITAR
United Nations Development Programme UNDP
United Nations Industrial Development Organization UNIDO
United Nations Environment Programme UNEP
United Nations University UNU
United Nations Special Fund
World Food Council
United Nations Centre for Human Settlements HABITAT
United Nations Fund for Population Activities UNFPA
Regional commissions
Functional commissions
Sessional, standing and ad hoc committees
IAEA International Atomic Energy Agency
GATT General Agreement on Tariffs and Trade
ILO International Labour Organization
FAO Food and Agriculture Organization of the United Nations
UNESCO United Nations Educational, Scientific and Cultural Organization
WHO World Health Organization
IMF International Monetary Fund
IDA International Development Association
IBRD International Bank for Reconstruction and Development
IFC International Finance Corporation
ICAO International Civil Aviation Organization
UPU Universal Postal Union
ITU International Telecommunication Union
WMO World Meteorological Organization
IMCO Inter-Governmental Maritime Consultative Organization
WIPO World Intellectual Property Organization
IFAD International Fund for Agricultural Development

April 1981

ternational Hydrologic Decade (IHD) (1965-1974) Unesco launched its International Hydrology Program (IHP) in 1975 with the objective of putting the vast amount of hydrologic knowledge accumulated during the decade by some 112 countries (Canada itself invested almost $43 million) to practical use by developing a sound scientific and technological basis for water resource management practices. Working closely with the World Meteorological Organization (WMO) Operational Hydrology Program and World Climate Programs, and with other related programs of UN agencies, the IHP especially seeks to provide developing nations with guidance on education, methodologies and operational practices for use by its water resource managers. The three phases of the IHP are planned through the joint efforts of Unesco and WMO by means of intergovernmental conferences held every six years.

The Ist phase (1975-1980) was largely devoted to completing studies and publishing guidance material started during the IHD.

The 2nd phase (1981-1983) concentrates more on the application of water sciences to problems of water management, and on an interdisciplinary approach to problems raised by multi-purpose water use in different climatic, economic and social conditions. The educational projects aim at the introduction of modern teaching methods, the education and training of technicians at the intermediate level and the preparation of a manual of comparative hydrology relating to the various hydrological regimes of the world. The emphasis placed on the education and training program will correspond to the needs of developing countries. Much of the Canadian effort in this phase is directed towards the preparation of technical manuals on hydrological processes in urbanized areas and towards the development of hydro-ecological indices for use in the assessment of the environmental impact of water projects.

The 3rd phase (1984-1989) will be used as a period of consolidation to bring all the knowledge together and evaluate the results for practical application. In preparation for this phase a major WMO/Unesco conference was held in 1981.

Man and the Biosphere Program: The Man and the Biosphere Program (MAB) was established in 1970 as a follow-up to the International Biological Program. An International program of research and training, it is active in more than 100 countries and is directed towards the development of scientific knowledge and the training of personnel to manage the world's natural resources. Fourteen project areas have been established, several of which involve water resources. The various MAB National Committees sponsor field research projects within these areas. In mid-1980 there were almost 1000 such projects in 74 countries with over 10 000 participants. Projects in similar ecological zones are linked through regional and international coordination networks.

Canada has participated in the MAB program from its inception. Activities are guided by a national committee with representation from governments, universities and the private sector. The Canadian Secretariat for MAB is now with the Canadian Committee for Unesco, having previously been with Environment Canada. Financial support for the program is provided by the federal departments of Environment, Fisheries and Oceans, Indian and Northern Affairs, and the National Research Council. Administrative overhead is provided by the Canada Council.

Numerous MAB research projects have been undertaken in Canada, resulting in many publications. Of particular interest is the program area concerning the conservation of natural areas for ecosystem study. Two areas, known as biosphere reserves, have been set up in Canada – Mont. St. Hilaire and Waterton Lakes National Park. Some 200 such areas have been created throughout the world.

United Nations Environment Program

The United Nations Environmental Program (UNEP) was established on the basis of recommendations arising from the UN's Stockholm Conference on the Human Environment held in 1972. Its purpose is to monitor significant changes in the environment and to encourage and coordinate sound environmental practices. To this end, Earthwatch, an international surveillance network, has been set up. One of its components, the Global Environmental Monitoring System, is designed to provide information for anticipating and combatting adverse environmental changes. One aspect of Canada's involvement in the System is reported under the World Health Organization, Collaborating Centre on Surface and Groundwater Quality. By the end of 1979 some 800 projects had been approved by UNEP in such areas as rural and urban ecology, development and its relationship to environment, natural disasters, the preservation of ecosystems such as tropical forests, the promotion of environmental law, marine pollution and energy production.

United Nations Development Programme

The United Nations Development Programme (UNDP) is the world's largest channel for multilateral technical and preinvestment cooperation. It is active in some 150 developing countries and territories and in virtually every economic and social sector. The more than 4 500 UNDP-supported projects currently under way aim at helping the developing countries make better use of their vast assets and expand productivity. Rendered only at the request of governments and in response to their priority needs, UNDP assistance is integrated into over-all national or regional development efforts and almost all projects are carried out by the United Nations itself or by one of 26 UN-related agencies and associated institutions. By the end of 1978, approximately $450 million was being spent annually to pay for the services of internationally recruited experts, the supply of imported technical equipment, specialized contract services and fellowship costs. UNDP activities are supported by virtually every member of the UN, and Canada is no exception.

A recent example of Canadian participation was the work undertaken by a former Environment Canada official in Egypt where a master plan for water resources development and use was prepared. This was jointly funded by the UNDP and the Egyptian government, and was coordinated by the World Bank. It follows the normal funding pattern for UNDP projects – the receiving country paying for at least half of the total cost. Projects now undertaken annually under the auspices of the UNDP exceed the $1 billion mark. Another typical example was Ontario's recent involvement in a 3 1/2 year, $1 million environmental study of the Tagus Estuary in Portugal. Ontario contributed through the provision of expert services, UNDP contributed to the funding and UNESCO was the coordinating agency. Environment Canada is currently participating in snow hydrology studies in the

Himalayas for the purpose of alleviating flooding in the Yamuna River basin in northern India.

The UNDP also acts as a mechanism for funding, coordinating and administering the training of foreign Fellows from developing countries through voluntary contributions from members. Over the past decade, more than $250 000 000 has been made available by the UNDP for such activities.

In Canada, numerous UNDP Fellows have visited universities and government offices for periods ranging from contact training for a month or two, to four year university degree programs, in order to gain skills and training beneficial to their work in water resources and hydrology in their home countries. For example, during the last six years, students from Brazil, Guinea, India, Kenya, Liberia, Malawi, Nigeria, Tanzania and Uganda have received UNDP fellowships to pursue studies under the WMO hydrology program in areas such as snow and ice hydrology, hydrometeorological networks, hydrological data collection and management, stochastic hydrology, lake regulation, hydroelectric reservoir design and hydrogeology. The Universities of Ottawa, Waterloo, Manitoba, Guelph, Toronto and McGill and the Kelsey Institute of Applied Arts and Sciences were involved, as was Environment Canada.

World Health Organization

The aim of the World Health Organization (WHO) is to see the world's population enjoying the highest possible level of health. The role of water in the afflictions thrust on third world countries has already been mentioned as has the International Drinking Water Supply and Sanitation Decade (1981-1990) which is coming to grips with the issue. Canada's main interest in water-related WHO activities centres on the revision of the 1971 WHO drinking water standards. Several Canadian government departments, led by National Health and Welfare, are assisting WHO in this area.

Collaborating Centre on Surface and Ground Water Quality: Over the past 30 years WHO has recognized a select number of research institutes around the world, usually one institute per field of specialization, as centres of excellence in that specific field, and designated them as WHO Collaborating Centres (WHO/CC). Such centres are committed to carrying out certain international activities whose broad objectives are to bring about improved precision, reliability, consistency, comparability in practice, and better results from national and international studies among the member states of the United Nations in the management and surveillance of surface and ground water quality. In October 1974, the Canada Centre for Inland Waters was designated by the World Health Organization as the WHO Collaborating Centre on Surface and Ground Water Quality. The main function of the Centre is to coordinate activities aimed at establishing (1) uniform or compatible methods of measuring and monitoring surface and ground water quality as a basis for public health action, (2) uniform or compatible instrumentation of measurement, and (3) uniform or compatible data storage and retrieval systems.

Since 1977, the WHO/CC has assumed the responsibility for coordinating the establishment of a worldwide network of water quality monitoring stations on major rivers, lakes and aquifers. The network is an integral component of the United Nations Environment Program's Global Environmental Monitoring System (GEMS), whose main objective is to monitor the long-term trends in environmental pollution. By late 1979, some 388 stations in 62 countries had been designated, 286 of which were providing comprehensive water quality data at the end of 1981.

Noteworthy among other WHO/CC activities are: (i) the publication, since 1976, of a quarterly journal WATER QUALITY BULLETIN in separate English and French editions, for distribution in some 150 countries around the world; (ii) organization of regional training courses in Africa, Southeast Asia, Latin America, the Western Pacific and Eastern Mediterranean; (iii) technical assistance in water management, laboratory operations and data storage and retrieval through Canadian consultants to such countries as Mexico, Peru, Costa Rica, Argentina, Brazil, Nigeria, Egypt and the Philippines, and (iv) acceptance for training and specialization of chemists, engineers and technologists from developing countries in Canada.

World Meteorological Organization

The World Meteorological Organization was formed in 1951 and is concerned primarily with the coordination of operational meteorological techniques and systems on a global scale. The World Weather Watch and the World Climate Program (conducted jointly with the International Council of Scientific Unions) are two of the high priority programs of WMO. This agency is organized geographically and by scientific subdiscipline into six Regional Associations, one of which is North- and Central America; and eight Technical Commissions, including the Commission for Hydrology. The other Commissions cover such areas as marine, aeronautical, agricultural and climatological aspects, as well as research in

Participants at a GEMS training course held in Lima, Peru for the benefit of countries of Latin America.

atmospheric sciences and establishment of standards for instruments and basic systems.

Canada plays a prominent role at each level of WMO, with the head of its Atmospheric Environment Service serving as the WMO Permanent Representative for Canada and as an elected member of the Executive Committee. Of the eight Technical Commissions, Canadians have recently served as Presidents on five, including the current President of the Commission for Hydrology.

Two examples of major initiatives by WMO in the field of hydrology serve to illustrate its scope and interests – the Hydrological Operational Multipurpose Subprogram (HOMS) and Pilot Projects on the Application of World Weather Watch to Hydrology.

HOMS is a mechanism for institutionalized transfer of technology, operational techniques and knowledge between countries on a world scale. The Canadian HOMS Centre is located within Environment Canada. In 1981, the first HOMS Reference Manual was distributed by WMO to over 45 centres established in individual countries or groups of countries. The Manual contains short descriptions of documents, operational procedures, techniques, instruments, etc, with an indication of their applicability and availability. At the time of release of the first edition, over 300 descriptions or components had been compiled, almost 50 of which came from Canada. Although now in its initial implementation stage, HOMS is expected to become, within a few years, a focus for the efficient transfer of knowledge, particularly to the Third World.

The second example relates to the World Weather Watch, a system coordinated by WMO which enables the world's meteorological services to exchange observations and forecasts around the world on a six-hourly basis in order to predict the weather into the near future. The link between this system and operational hydrology is being investigated and improved through pilot studies on selected river basins in each Region. The first such pilot project to be completed took place in the Saint John River basin and covered parts of New Brunswick and the State of Maine and involved 16 agencies from Canada and the United States over a three year period. The results of the project, which were reviewed at an international workshop sponsored by WMO in 1979, served as a catalyst to the development of similar projects elsewhere, particularly in South America.

Canadian International Development Agency

The Canadian International Development Agency (CIDA) is the principal Canadian agency involved in the provision of bilateral aid to developing countries. Over the past decade, grants and concessionary loans of some $300 million have been provided to some 26 countries and regions to assist them in the investigation, development and operation of water resources for agriculture, domestic and municipal use and for the generation of electrical energy. These grants and loans have, in turn, funded the supply of Canadian goods and services to the recipient country. Many Canadian government departments, public agencies and consulting firms are involved in the development, implementation and management of these programs. Recently completed water resources projects involving CIDA include the Lower Ruvu Water Treatment and Pumping Plant (including transmission mains and reservoir) for the City of Dar es Salaam, Tanzania; the master water plan for the Coast Region and Dar es Salaam Region; rural water supply projects in the Upper Region of Ghana, consisting of the siting and construction of some 2300 deep wells and the installation of hand pumps and the design and construction of three small urban water systems; design and construction of a water treatment plant, transmission mains, local water mains and sewer, and waste water treatment for the City of Belize, Central Africa and environs.

CIDA has currently committed approximately $200 million in grants and loans to fund the Canadian inputs to some 50 water projects being undertaken in 20 developing countries and regions. Included are irrigation schemes in Sri Lanka, Nepal, Tunisia and Indonesia; technical assistance to international commissions for the Gambia, Senegal and Niger Rivers; a major water treatment and pumping plant for municipal water supply to Accra-Tema and its surrounding area in Ghana; various assessment, planning, design, construction and institutional development projects for agricultural, rural and small water supply projects in the Ivory Coast, Mali, Niger, Cameroun, Togo, Ghana, Ethiopia, Kenya, Malawi, Zimbabwe, Mozambique, Mauritius, Swaziland, Bangladesh, Pakistan and Northern Nigeria; and research associated with the effect of rainfall or of limited water conditions on agriculture in Tanzania, India and Sri Lanka.

Current commitments to water resources and to rural and urban water supply projects constitute about 8-10% of the total annual budget of CIDA's Bilateral Program. Additional programs for single purpose hydroelectric projects are funded under the Energy Sector Program.

In any water-related programs overseas, it has been found that a high level of user involvement and training is essential to the acceptance and successful operation of the program.

Increased efforts in water resource development will be required to meet the ever-increasing demands in developing countries for agricultural production. Likewise, increased water resource activity in small hydroelectric power generation and in wind and solar powered pumping will no doubt follow from the UN Conference on New and Renewable Energy, recently convened in Nairobi, Kenya.

The experience of CIDA, other donor agencies and the developing countries themselves indicates that the most serious constraint to water resource development is the shortage of suitably qualified manpower to plan, implement, operate, maintain and manage both existing and required water resource facilities. Rapidly escalating costs are also a serious constraint – coupled with the fact that water resource development projects must compete with other key development needs in the agricultural, energy and housing sectors. Increased attention must be given to the use of technologies which are appropriate, economic and acceptable in terms of their environmental and social impact. In the area of domestic water supply, attention must be paid to related projects in waste water disposal, sanitation and public health in order to achieve and sustain the benefits which are attributed to the supply of water of improved quality and accessibility. In the case of rural water supplies in developing countries, it has been found that a high level of user involvement and training is essential to the acceptance and successful operation of the system.

International Bank for Reconstruction and Development

The International Bank for Reconstruction and Development, also known as the World Bank, directs its efforts towards reconstruction and development within member countries by facilitating capital investment for productive purposes. The Bank operates in part as a funding organization but also provides a wide range of technical assistance services. The areas of the development strategy which most reflect water interests are those in the agricultural and rural development sectors. Canada is a member and participates in the Bank's decision-making processes and contributes either through direct financial assistance or through the provision of expertise. An example of the latter, a joint World Bank/United Nations Development Programme project to produce a master plan for Egypt's water resources, has already been cited in the UNDP section – a project which typifies the cooperative multi-organizational approach which is commonplace in such programs. Other examples include:

The Canadian government is currently providing financial assistance, as is the World Bank and the European Economic Community, to the Sri Lankan government for completion of the first stage of a master plan for the provision of a reliable clean water supply to the city of Colombo and towns in the coastal strip to the north and south. Canada is contributing $6 million to the $51.4 million project.

A Canadian consultant has been commissioned by the Bank to develop a Project Preparation Handbook with a view to standardizing the procedures and requirements of the various international agencies involved in funding water and sanitation projects in developing countries.

The World Bank, CIDA and the African Development Bank have undertaken a water supply project for the Accra Tema Metropolitan Area in Ghana involving construction of an earth dam at Weija, a pumping station, additional water treatment facilities, reservoir capacity and over 20 miles of distribution pipeline. Canadian consultants, financed by CIDA, are supervising all components other than the dam and are responsible for the installation of the pumping station and treatment plant.

Also in west Africa, the World Bank and CIDA are involved in the Kano State Water Supply Project in Northern Nigeria. CIDA financed a Canadian consultant to undertake a project report for the expansion of the state water supply and to provide new or improved supplies for more than 150 small towns in Kano State.

Other Multinational Organizations

Separate from the complex United Nations Family are other intergovernmental organizations in which Canadians take part. The principal ones, which are indicated in Table 16, are described below.

Organization for Economic Cooperation and Development

The Organization for Economic Cooperation and Development (OECD) is an intergovernmental body representing 24 industrialized countries. Recognizing the conflicts between economic growth and protection of the environment, an Environment Committee was established in 1970. The Committee is assisted by a number of specialized subsidiary groups concerned with specific aspects of environmental policy such as air, water, chemicals, waste management, urban affairs, land use, noise, energy and transportation. Over the past few years, Canada has played a major role in OECD water management projects with involvement in such areas as eutrophication control, control of organo-

OECD	Organization for Economic Coroporation and Development Environmental Committee/Water Management Policy Group	 Environment Canada (EPS)
NATO	North Atlantic Treaty Organization Committee on the Challenges of Modern Society	Environment Canada
EEC	European Economic Community	Environment Canada

EPS – Environmental Protection Service

chlorinated compounds in drinking water, pollution control, the design and appraisal of multipurpose hydraulic projects and the development of methodologies for assessing environmental damage costs. More recently Environment Canada has become involved in a study on diffuse sources of water pollution. This project, which will address both urban and agricultural sources, will attempt to assess the magnitude of this problem across OECD member countries and identify appropriate management practices.

North Atlantic Treaty Organization

The North Atlantic Treaty Organization (NATO) encourages member countries to cooperate politically, economically, and socially without duplicating work of other international organizations. Efforts are directed towards government policy formulation and legislation.

In 1969, NATO established the Committee on the Challenges of Modern Society (CCMS), whose purpose, like that of the OECD Environment Committee, is to harmonize industrial and economic development with environmental concerns. The CCMS method of operation is largely by way of an action-oriented 'pilot country' approach in which one country accepts responsibility for a project which it considers to be worth doing. It plans the study, pays for it and prepares all the necessary documentation. Thus projects tend to be undertaken only when there is a serious intention to do the work well. Under this arrangement only those members countries who are actively concerned about the same problem participate in the Pilot Project.

In the early 1970s, CCMS agreed that an Inland Waters Pollution project should be undertaken and that it should demonstrate ways in which countries can cooperate to reduce pollution and develop techniques for water quality management. Canada undertook to act as the pilot country and designated the comprehensive river basin planning and management program for the Saint John River as the focus for the Canadian contribution to the project. Canada also participated in a United Kingdom pilot project on Advanced Wastewater Treatment initiated in 1972 at Rye Meads in England. Canada is presently participating in an Estuary Management Study involving the sharing of data and experiences with six NATO member countries concerning the planning and management of major estuaries; Canada's contribution has been a joint Canada-British Columbia report on the Fraser Estuary. Through the Department of National Health and Welfare, Canada is actively participating in a NATO drinking water project with a view to achieving a better understanding of the problems occurring in industrialized countries.

Other Institutional Arrangements

Although bilateral, and multilateral scientific exchange agreements have been in effect with several countries over the last few years, there are relatively few formal arrangements now in effect as far as water management is concerned. In 1979, Canada hosted a technology exchange workshop on water pollution control technologies for the 1980s, under a Canada/Germany Science and Technology Agreement. All Canadian sectors were represented. Environment Canada has been participating with the European Economic Community (EEC) on a project for the treatment and disposal of sewage sludge. Efforts are now being made to formalize these wastewater research activities through a Canada/EEC Memorandum of Understanding. Canada, the United States and the United Kingdom are currently cooperating in a study to evaluate various computer models for their use in wastewater treatment. Environment Canada's Wastewater Technology Centre is cooperating with other countries including Scandinavia, Europe, the United Kingdom and the United States in several projects aimed at improving the operation and energy costs of wastewater treatment plants through automation. Future efforts will include participation in a proposed International Instrumentation Test and Evaluation Program designed to evaluate commercial instrumentation for wastewater treatment.

Early 1970 saw the termination of 40 man-years of effort in Northern Ghana by the Prairie Farm Rehabilitation Administration (PFRA). The objectives were two-fold; to investigate and design irrigation projects and to establish training programs. The training for Ghanaian engineers was provided through working directly with senior PFRA staff in Ghana as well as in PFRA offices in Canada.

International Scientific Organizations

Another area of extensive international involvement by Canadians is that of the international scientific community. One of the most important groups from the water point of view is that of the International Council of Scientific Unions (ICSU), a non-governmental organization whose membership is drawn from recognized scientific institutions. The ICSU family is shown in Table 17. It has established links with various intergovernmental organizations such as Unesco, ECOSOC, UNEP, WMO, FAO, and WHO and with other non-governmental organizations. Canada is represented on most of ICSU's major unions and committees which have an interest in freshwater activities – three of the more important being the International Geographical Union, the International Union of Geological Sciences and the International Union of Geodesy and Geophysics (IUGG). Of these three, the IUGG especially relates to water interests mainly through its International Association of Hydrological Sciences (IAHS) and the International Association of Meteorology and Atmospheric Physics. The National Research Council's Associate Committee on Hydrology is designated as the Canadian Committee for the IAHS and its six international commissions on Surface Water, Groundwater, Snow and Ice, Continental Erosion, Water Quality and Water Resource Systems, and its International Committee on Remote Sensing and Data Transmission for hydrology.

There are also a number of special committees under ICSU whose purpose is to coordinate scientific studies and programs that cross the disciplinary boundaries of its unions. Those that relate to water are the Scientific Committees which deal with Water Research, Antarctic Research, Problems of the Environment, and Oceanic research; the former joint WMO/ICSU committee for the Global Atmospheric Research Program which has now been replaced by the World Climate Program; and the Federation of Astronomical and Geophysical Services – the latter maintaining the Permanent Service on Fluctuation of Glaciers. One important independent but closely associated body is the International Association for Water Pollution Research.

There are also many other independent scientific organizations with varying water resource interests. Some of the more important ones are listed at the bottom of Table 17.

Other Involvement

Canada participates in various programs geared to the education and research needs of the natural sciences community.

Grants and scholarships are awarded under various scientific exchange programs arranged by the Natural Sciences and Engineering Research Council (NSERC). In recent years, research in the natural sciences has been promoted through institutional and university exchanges with Brazil, the USSR, Japan and Czechoslovakia. NSERC also administers various programs on behalf of other agencies, organizations and government departments.

CIDA/NRC scholarships and fellowships are made available on a government to government basis to those developing countries with which Canada has technical assistance agreements. CIDA research associateships enable overseas students and scientists to further their research objectives at Canadian institutions.

A Canada/France cultural exchange agreement is sponsored by External Affairs and involves many Canadian and French scientists and researchers.

NATO Postdoctoral Fellowships are avail-

The ICSU Family

ICSU	International Council of Scientific Unions	National Research Council
IUGG	International Union of Geodesy and Geophysics (1919)	National Research Council
IAHS	International Association of Hydrological Sciences	Environment Canada (ECS)
	International Commission on Continental Erosion	Laval University (Quebec)
	International Commission on Surface Water	Environment Alberta
	International Commission on Ground Water	Environment Canada (ECS)
	International Commission on Snow and Ice	Environment Canada (ECS)
	International Commission on Water Quality	Environment Canada (ECS)
	International Commission on Water Resource Systems	Environment Canada (ECS)
	International Committee on Remote Sensing and Data Transmission	Saskatchewan Research Council Environment Canada (AES)
IAMAP	International Association of Meteorology and Atmospheric Physics	Environment Canada (AES)
IUGS	International Union of Geological Sciences (1961)	Canadian Geoscience Council
IAH	International Association of Hydrogeologists	
IAWPR	International Association for Water Pollution Research (1974)	Environment Canada (ECS)
SCAR	Scientific Committee on Antarctic Research (1958)	Environment Canada
COWAR	Scientific Committee on Water Research (1964)	Environment Canada
CODATA	Committee on Data for Science and Technology	National Research Council
SCOPE	Scientific Committee on Problems of the Environment	National Research Council
FAGS	Federation of Astronomical and Geophysical Services (1956) (Permanent Service on Fluctuation of Glaciers)	

Other Scientific Organizations

AGID	Association of Geoscientists for International Development	Episodes Secretariat 601 Booth St., Ottawa
IAHR	International Association on Hydraulic Research	National Research Council
ICID	International Commission on Irrigation and Drainage	Agriculture Canada
ICOLD	International Commission on Large Dams	Environment Canada (ECS)
IOS	International Organization on Standardization	Environment Canada (ECS)
IWRA	International Water Resources Association	Environment Canada (ECS)
IIASA	International Institute for Applied Systems Analysis	Institute for Research on Public Policy – Montreal
ICAE	International Commission of Agricultural Engineers	
ISSS	International Soil Science Society	

AES – Atmospheric Environment Service
ECS – Environmental Conservation Service

able for Canadians wishing to pursue their studies in other NATO Countries, and vice versa.

The National Research Council, responding to recommendations from the 1979 Conference on Science and Technology for Development has organized an activity entitled Science and Technology for Development for the purpose of improving the technical and scientific capability of developing countries. This is accomplished through promoting the provision of expert assistance to developing countries through the use of NRC services and laboratory facilities, and by identifying areas of mutual interest, establishing contacts, hosting visitors, etc.

Many government departments award overseas students with Visiting Fellowships to Canadian government laboratories.

The Council of (provincial) Ministers of Education has an arrangement with the People's Republic of China which enables Chinese scientists to pursue their interests in Canada

Related Agencies

The Canadian University Services Overseas (CUSO) is engaged in ongoing rural water supply projects in Malaysia, Thailand, Zimbabwe, Mozambique and Sierre Leone. These include such work as reservoir development, pumping systems, the provision of boreholes and wells, etc.

An organization which technically may not qualify for inclusion, but which nevertheless should be mentioned, is the International Development Research Centre. The Centre is unique among international institutions. Funded by an annual grant from the Parliament of Canada, the Centre is an autonomous organization whose policies are set by an independent board of governors representing Canada, the industrialized nations, and the Third World. In 10 years of operations, the Centre has funded more than 900 projects in 100 countries addressing concerns in the agricultural, information sciences, health and social sciences sectors. Some of the activities of this organization are related to the water resource management scene inasmuch as the Centre's aim is to initiate, encourage, support and conduct research into the problems of the developing regions of the world and into the means for applying and adapting scientific, technical and other knowledge to the economic and social advancement of those regions. It does this through providing support for Third World Scientists to carry out research on subjects they feel are important in their own national context. Centre staff provide guidance in identifying and developing research projects, and assist where necessary in the execution of the research.

Canadian involvement not addressed here includes the Anglican Church of Canada, the Catholic Organization for Development and People, Oxfam, the Menonite Central Committee, the United Church of Canada, Division of World Outreach, the Cooperative Development Foundation, C.A.R.E., the Canadian Save the Children Funds, and Unicef.

Future Involvement

The launching of the Drinking Water Supply and Sanitation Decade (1981-1990) is expected to increase activity in both developing and donor countries. It is expected that the level of Canadian input to this and to related water sector programs in developing countries will be sustained, if not increased. Any change will likely involve an increased emphasis on bilateral programs, with slightly less reliance on the multinational approach. The Secretary of State for External Affairs expressed it well when he said "Canadians can look back on 30 years of creative participation in the Third World's struggle for a better life, and forward to unlimited opportunities to help create a more just and civilized international system. This is the biggest and most important piece of unfinished work facing us in the foreseeable future, and our efforts in this direction – whether of money or of ideas, of people or of economic structuring – are the best investment we can make today."

Photo Credits

Agriculture Canada: page 15

British Columbia Hydro and Power Authority: pages 9, 70

Collaborating Centre on Surface and Ground Water Quality, CCIW: pages 99, 100

DREE: pages 18, 52

Environment Canada: pages 12, 24, 25, 27, 30, 39, 60, 63, 67, 73, 76, 79, 82, 85

Environment Ontario: page 80

Manitoba Hydro: page 90

National Film Board Photothèque: cover and pages 12, 16, 20, 22, 28, 32, 40, 50, 75

National Research Council: page 94

Ontario Hydro: page 38

Quebec Hydro: page 88

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS DIRECTORATE

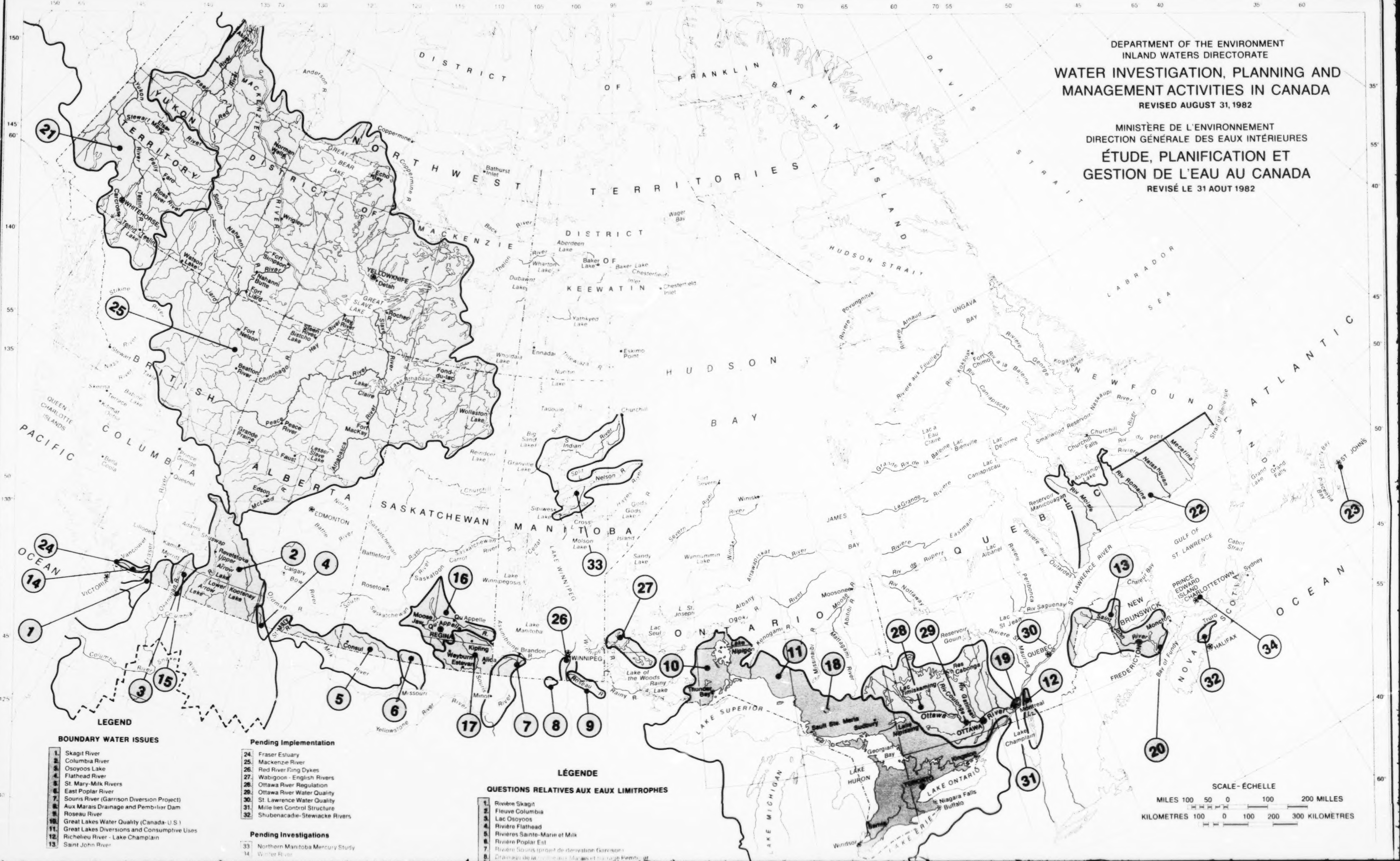
WATER INVESTIGATION, PLANNING AND MANAGEMENT ACTIVITIES IN CANADA

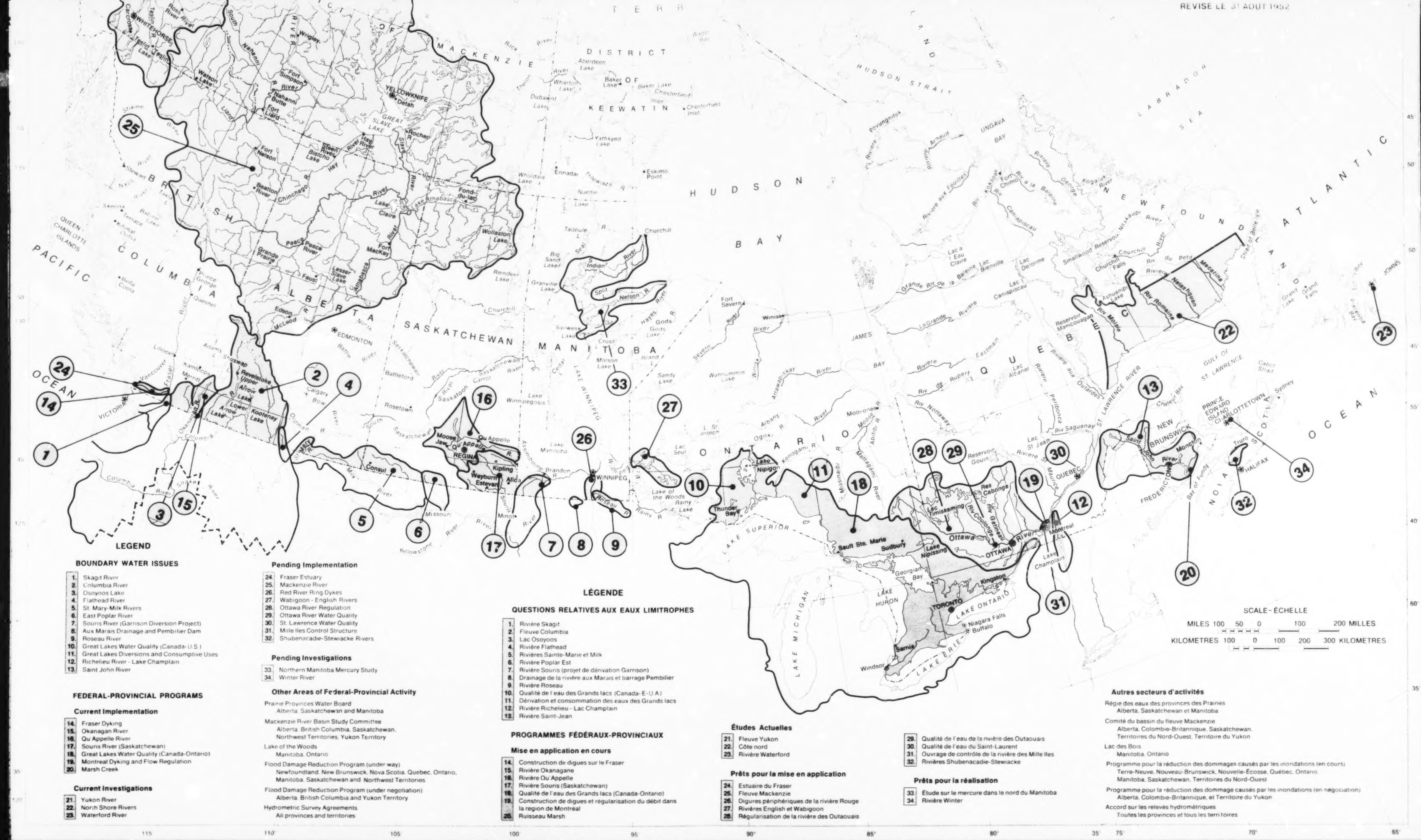
REVISED AUGUST 31, 1982

MINISTÈRE DE L'ENVIRONNEMENT
DIRECTION GÉNÉRALE DES EAUX INTÉRIEURES

ÉTUDE, PLANIFICATION ET GESTION DE L'EAU AU CANADA

REVISÉ LE 31 AOUT 1982


LEGEND
BOUNDARY WATER ISSUES
1. Skagit River
2. Columbia River
3. Osoyoos Lake
4. Flathead River
5. St. Mary-Milk Rivers
6. East Poplar River
7. Souris River (Garrison Diversion Project)
8. Aux Marais Drainage and Pembilier Dam
9. Roseau River
10. Great Lakes Water Quality (Canada-U.S.)
11. Great Lakes Diversions and Consumptive Uses
12. Richelieu River - Lake Champlain
13. Saint John River
Pending Implementation
24. Fraser Estuary
25. Mackenzie River
26. Red River Ring Dykes
27. Wabigoon - English Rivers
28. Ottawa River Regulation
29. Ottawa River Water Quality
30. St. Lawrence Water Quality
31. Mille Iles Control Structure
32. Shubenacadie-Stewiacke Rivers
Pending Investigations
33 Northern Manitoba Mercury Study
34 Winter River
LÉGENDE
QUESTIONS RELATIVES AUX EAUX LIMITROPHES
1. Rivière Skagit
2. Fleuve Columbia
3. Lac Osoyoos
4. Rivière Flathead
5. Rivières Sainte-Marie et Milk
6. Rivière Poplar Est
7. Rivière Souris (projet de dérivation Garrison)
8. Drainage de la rivière aux Marais et barrage Pembilier
SCALE - ÉCHELLE
MILES 100 50 0 100 200 MILES
KILOMETRES 100 0 100 200 300 KILOMETRES
DISTRICT OF FRANKLIN
BAFFIN ISLAND
DAVIS STRAIT
NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE
DISTRICT OF KEEWATIN
YUKON TERRITORY
HUDSON STRAIT
LABRADOR SEA
HUDSON BAY
JAMES BAY
UNGAVA BAY
ATLANTIC OCEAN
PACIFIC OCEAN
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
PRINCE EDWARD ISLAND
GULF OF ST LAWRENCE
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
LAKE ONTARIO
LAKE WINNIPEG
WHITEHORSE
YELLOWKNIFE
EDMONTON
REGINA
WINNIPEG
TORONTO
OTTAWA
QUEBEC
FREDERICTON
CHARLOTTETOWN
HALIFAX
ST. JOHNS
VICTORIA
Vancouver
Calgary
Saskatoon
Montreal
Moncton
Sydney
Truro
Thunder Bay
Sault Ste. Marie
Sudbury
Kingston
Sarnia
Windsor
Niagara Falls
Buffalo
Churchill
Moosonee
Great Bear Lake
Great Slave Lake
Lake Athabasca
Wollaston Lake
Reindeer Lake
Lake Winnipegosis
Lake Manitoba
Lake of the Woods
Lake Nipigon
Lake Nipissing
Georgian Bay
Lake Champlain
Lac Seul
Lac St Jean
Smallwood Reservoir
Reservoir Gouin
Reservoir Manicouagan
Bay of Fundy
Cabot Strait
Strait of Belle Isle
Mackenzie River
Peace River
Athabasca River
Nelson R.
Churchill River
Saskatchewan River
Fraser River
Columbia River
Ottawa River
St. Lawrence River
Saint John River
Rainy R.
Missouri
Yellowstone River
Milk River
Souris River
21 22 23 24 14 1 15 3 2 4 5 6 16 17 7 8 9 26 27 33 10 11 18 28 29 19 12 31 30 20 13 32 34 25


REVISE LE 31 AOUT 1982
DISTRICT OF MACKENZIE
DISTRICT OF KEEWATIN
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEW BRUNSWICK
NOVA SCOTIA
PRINCE EDWARD ISLAND
NEWFOUNDLAND
LABRADOR SEA
HUDSON STRAIT
HUDSON BAY
JAMES BAY
UNGAVA BAY
GULF OF ST. LAWRENCE
PACIFIC OCEAN
ATLANTIC OCEAN
WHITEHORSE
YELLOWKNIFE
EDMONTON
REGINA
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OTTAWA
QUEBEC
FREDERICTON
HALIFAX
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ST. JOHNS
VICTORIA
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LAKE MICHIGAN
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SCALE - ÉCHELLE
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KILOMETRES 100 0 100 200 300 KILOMETRES
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110°
105
100
95
90°
85°
80°
75°
70°
65°

LEGEND

BOUNDARY WATER ISSUES

- 1. Skagit River
- 2. Columbia River
- 3. Osoyoos Lake
- 4. Flathead River
- 5. St. Mary-Milk Rivers
- 6. East Poplar River
- 7. Souris River (Garrison Diversion Project)
- 8. Aux Marais Drainage and Pembilier Dam
- 9. Roseau River
- 10. Great Lakes Water Quality (Canada-U.S.)
- 11. Great Lakes Diversions and Consumptive Uses
- 12. Richelieu River - Lake Champlain
- 13. Saint John River

FEDERAL-PROVINCIAL PROGRAMS

Current Implementation

- 14. Fraser Dyking
- 15. Okanagan River
- 16. Qu'Appelle River
- 17. Souris River (Saskatchewan)
- 18. Great Lakes Water Quality (Canada-Ontario)
- 19. Montreal Dyking and Flow Regulation
- 20. Marsh Creek

Current Investigations

- 21. Yukon River
- 22. North Shore Rivers
- 23. Waterford River

Pending Implementation

- 24. Fraser Estuary
- 25. Mackenzie River
- 26. Red River Ring Dykes
- 27. Wabigoon - English Rivers
- 28. Ottawa River Regulation
- 29. Ottawa River Water Quality
- 30. St. Lawrence Water Quality
- 31. Mille Iles Control Structure
- 32. Shubenacadie-Stewiacke Rivers

Pending Investigations

- 33. Northern Manitoba Mercury Study
- 34. Winter River

Other Areas of Federal-Provincial Activity

Prairie Provinces Water Board
Alberta, Saskatchewan and Manitoba

Mackenzie River Basin Study Committee
Alberta, British Columbia, Saskatchewan, Northwest Territories, Yukon Territory

Lake of the Woods
Manitoba, Ontario

Flood Damage Reduction Program (under way)
Newfoundland, New Brunswick, Nova Scotia, Quebec, Ontario, Manitoba, Saskatchewan and Northwest Territories

Flood Damage Reduction Program (under negotiation)
Alberta, British Columbia and Yukon Territory

Hydrometric Survey Agreements
All provinces and territories

LÉGENDE

QUESTIONS RELATIVES AUX EAUX LIMITROPHES

- 1. Rivière Skagit
- 2. Fleuve Columbia
- 3. Lac Osoyoos
- 4. Rivière Flathead
- 5. Rivières Sainte-Marie et Milk
- 6. Rivière Poplar Est
- 7. Rivière Souris (projet de dérivation Garrison)
- 8. Drainage de la rivière aux Marais et barrage Pembilier
- 9. Rivière Roseau
- 10. Qualité de l'eau des Grands lacs (Canada-E-U A)
- 11. Dérivation et consommation des eaux des Grands lacs
- 12. Rivière Richelieu - Lac Champlain
- 13. Rivière Saint-Jean

PROGRAMMES FÉDÉRAUX-PROVINCIAUX

Mise en application en cours

- 14. Construction de digues sur le Fraser
- 15. Rivière Okanagane
- 16. Rivière Qu'Appelle
- 17. Rivière Souris (Saskatchewan)
- 18. Qualité de l'eau des Grands lacs (Canada-Ontario)
- 19. Construction de digues et régularisation du débit dans la region de Montréal
- 20. Ruisseau Marsh

Études Actuelles

- 21. Fleuve Yukon
- 22. Côte nord
- 23. Rivière Waterford

Prêts pour la mise en application

- 24. Estuaire du Fraser
- 25. Fleuve Mackenzie
- 26. Digures périphériques de la rivière Rouge
- 27. Rivières English et Wabigoon
- 28. Régularisation de la rivière des Outaouais
- 29. Qualité de l'eau de la rivière des Outaouais
- 30. Qualité de l'eau du Saint-Laurent
- 31. Ouvrage de contrôle de la rivière des Mille Iles
- 32. Rivières Shubenacadie-Stewiacke

Prêts pour la réalisation

- 33. Étude sur le mercure dans le nord du Manitoba
- 34. Rivière Winter

Autres secteurs d'activités

Régie des eaux des provinces des Prairies
Alberta, Saskatchewan et Manitoba

Comité du bassin du fleuve Mackenzie
Alberta, Colombie-Britannique, Saskatchewan, Territoires du Nord-Ouest, Territoire du Yukon

Lac des Bois
Manitoba, Ontario

Programme pour la réduction des dommages causés par les inondations (en cours)
Terre-Neuve, Nouveau-Brunswick, Nouvelle-Écosse, Québec, Ontario, Manitoba, Saskatchewan, Territoires du Nord-Ouest

Programme pour la réduction des dommage causés par les inondations (en négociation)
Alberta, Colombie-Britannique, et Territoire du Yukon

Accord sur les relevés hydrométriques
Toutes les provinces et tous les territoires